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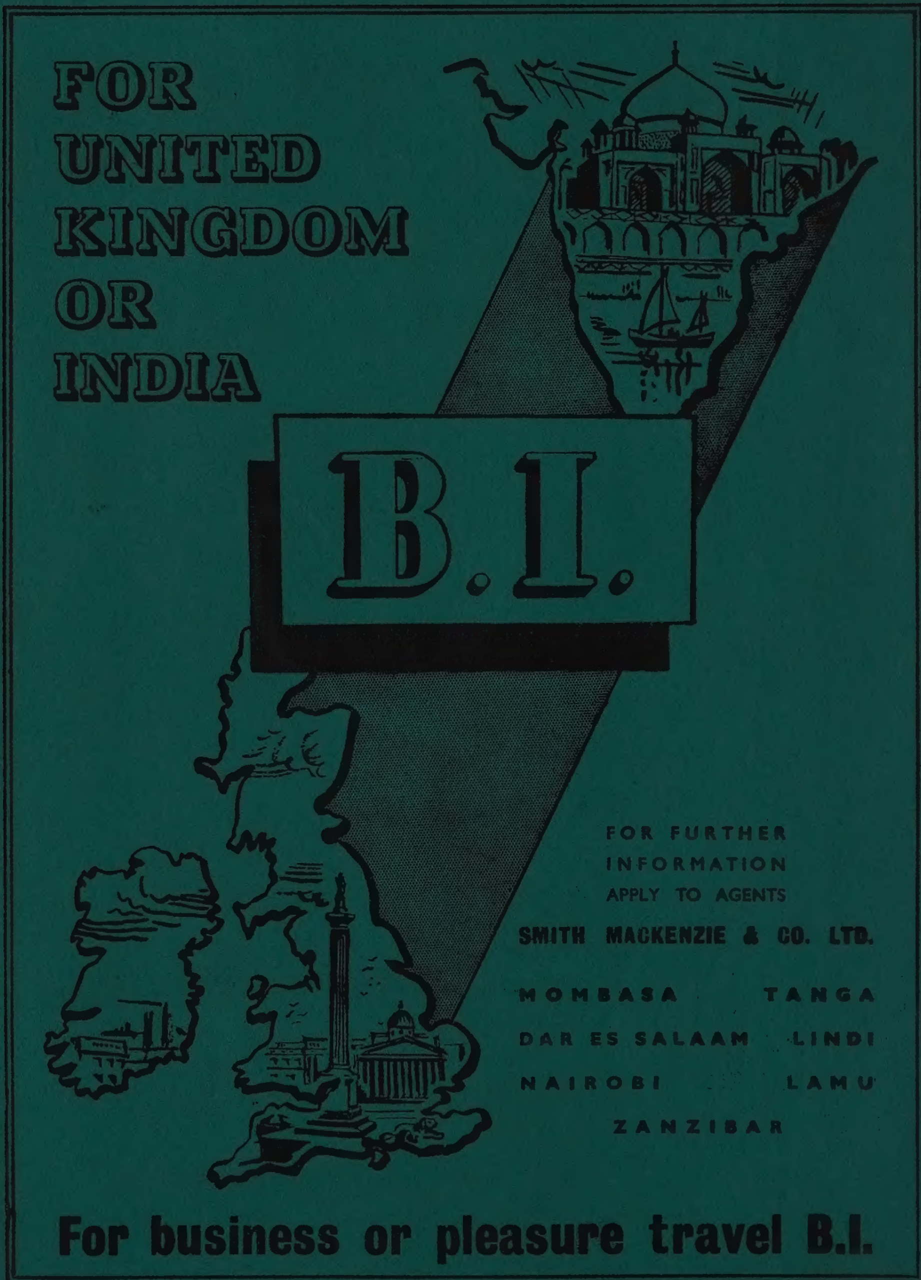
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THE

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Readers are reminded that all agricultural inquiries, whether they relate to articles in the Journal or not, should be addressed to the local Director of Agriculture, and not to the Editor.

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THE SUSCEPTIBILITY OF WOOD TO TERMITE ATTACK

By P. B. Kemp, Tsetse Research Department, Tanganyika Territory

(*Received for publication on 17th October, 1950*)

It has already been shown by various workers that termites select certain kinds of wood for attack; Wigg (1946) has demonstrated the durability of some East African timbers at Morogoro, and Sangster (1942) has carried out similar work in Uganda. The following observations were made using logs cut from trees and shrubs commonly found in the thicket around Shinyanga, in the Lake Province of Tanganyika.

Thirty species of trees were used in the experiment; the logs were cut 50 cm. in length and varying from 3 to 5 cm. in diameter. They were cut from green wood, the bark left on and driven into the ground to a depth of 20 cm. Twenty sites were selected for this work in thicket which is protected from fire and grazing. Five sites were selected in each of four different places, all having similar vegetation and a deep red sandy soil. Each species of tree was represented by one log in each site. A site therefore consisted of 30 logs, these were arranged in a square of 5 x 6 logs 50 cm. apart. The logs were arranged at random within each site (by reference to a table of random numbers and the numbers 1—30 allotted to the species used).

These logs were examined superficially at intervals of about two weeks, between 9 a.m. and 11 a.m. At the end of six months the logs were taken out for examination and immediately replaced. The results were assessed numerically by allotting a score to each log according to the degree of attack by termites. Unattacked = 0, slight attack = 1, much attacked = 2, almost consumed = 3. Such a method of observation is open to error, it was therefore repeated at the end of nine months, but the difference between these two sets of results was negligible. The total score allotted to each species of tree varied widely indicating the susceptibility of each kind of wood to attack. A further point of interest was gained by comparing the aggregate of scores for each site; these figures were practically constant, which suggests that there must be an even distribution of termites foraging for wood over the area selected. From these results the following list was compiled, indicating the extent to which each species was attacked:—

Readily attacked (score over 40)—

- *Sterculia africana* Fiori (Sterculiaceæ).
- *Commiphora fischeri* Engl. (Burseraceæ).
- *Commiphora ugogensis* Engl. (Burseraceæ).
- *Commiphora schimperi* Engl. (Burseraceæ).
- *Lannea humilis* Engl. (Anacardiaceæ).
- *Royena fischeri* Gürke ex Mildbr. (Ebenaceaæ).

Moderately attacked (score 5—40)—

- *Strophanthus eminii* Asch. and Pax (Apocynaceæ).
- *Hymenodictyon parvifolium* Oliv. (Rubiaceæ).
- *Combretum zeyheri* Sond. (Combretaceæ).
- *Markhamia obtusifolia* Sprague (Bignoniaceæ).
- *Combretum gueinzii* Sond. (Combretaceæ).
- *Combretum obovatum* Hoffm. (Combretaceæ).
- *Schrebera koiloneura* Gilg (Oleaceæ).
- *Cassia singueana* Del. (Cæsalpiniaceæ).
- *Dalbergia stuhlmanii* Taub. (Papilionaceæ).
- *Markhamia acuminata* K.Schum. (Bignoniaceæ).
- *Ziziphus mucronata* Willd. (Rhamnaceæ).
- *Teclea glomerata* Verdoorn (Rutaceæ).
- *Grewia platyclada* K.Schum. (Tiliaceæ).
- *Grewia bicolor* Juss. (Tiliaceæ).
- *Acacia drepanolobium* Harms (Mimosaceæ).
- *Fagara merkeri* Engl. (Rutaceæ).
- *Ostryoderris stuhlmanii* Dunn (Papilionaceæ).
- *Dalbergia melanoxylon* Guill. and Perr. (Papilionaceæ).

Almost unattacked (score under 5)—

- *Ormocarpum trichocarpum* Burtt Davy (Papilionaceæ).
- *Strychnos heterodoxa* Gilg (Loganiaceæ).
- *Dichrostachys glomerata* Chiov. (Mimosaceæ).
- *Acacia rovumæ* Oliv. (Mimosaceæ).
- *Abrus schimperi* Hochst. (Papilionaceæ).

Four species of termite were mainly responsible for the destruction of these logs, these were: *Ancistrotermes latinotus* Silvestri, *Allodontermes morogorensis* Harris, *Microtermes* sp. and *Microcerotermes parvus* Haviland. In addition, *Odontotermes latericius* and *Macrotermes bellicosus* were found rarely. When the

logs were first put out the signs of termite activity were extensive and not one species of tree had been ignored. This period of reconnaissance did not last long, in all future observations termite activity was concentrated on a few species. In addition there was some evidence that there was a decrease in termite activity during the dry season (July—October) but this has not been fully investigated.

Of the 30 species of tree referred to, 13 were included in Wigg's list. Although his work was carried out over a very much longer period, these results are in agreement with his experiments, with the exception of *Strychnos heterodoxa* which appears to lose its resistance to termite attack in the course of time. It appears that the woods which are most readily attacked are soft or with a pith; those which were almost unattacked were hard woods and some of them, for example, *Teclea glomerata* and *Fagara merkeri* contain volatile oils. Wolcott (1940), working in the West Indies, has also shown that termites tend to avoid woods which contain a large amount of gum.

ACKNOWLEDGMENTS

I am grateful to Mr. W. V. Harris for assistance with the identification of the termites, and to Dr. P. E. Glover for all the botanical information. The work was done during the tenure of a grant from the Colonial Development and Welfare Fund, and I am indebted to Mr. W. H. Potts for the facilities which have been made available.

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CORRESPONDENCE

The Editor,

The East African Agricultural Journal.

SIR,

Herewith is a description of a valve for use in irrigation work, which may be of interest to your readers.

The valve is a gate valve, made of concrete. Its construction is as follows: First make a box, tapering on all four sides, in which to cast the gate slab. The box should be perfectly smooth inside, and of such size that the resultant slab of concrete will be 2 in. to 3 in. thick at the small end, and 4 in. to 6 in. wider and 6 in. longer than the inside diameter of the pipe. The taper should be 1 in. per foot of length. Stand the box, which is open at both ends, on a flat level surface with the small end down, and place in it a loop of round iron of such length as will reach nearly to the bottom of the box, with the loop standing a few inches above the top. Bend out the lower ends of the loop, so that it will have a good grip on the concrete. This loop is for lifting the slab. Now cast the box full of 1:2:4 concrete, taking care that the box is completely filled and the concrete well rammed. Allow to set for a week, then break away the shuttering. Smooth up the tapered slab of concrete and fill up any small holes with 1:1 cement mortar. Now cover the slab all over with a good coat of grease (not oil), put on a smooth layer of paper, then another coat of grease. Cut a piece of wood exactly the size of the thin end of the slab, and ½ in. thick. Put the slab in place over the end of the pipe, with the piece of wood below it. The object of the wood is to leave a recess below the end of the slab, so that when the paper is finally removed from the slab, the slab will be a jam fit in its recess. The loop, of course, should be uppermost. Now cast concrete around the end of the pipe and the slab, leaving an opening on the outboard and the same size as the pipe, for the escape of the water when the slab is lifted. Allow to set for two weeks and the job is done. This valve is cheap, efficient, and even the native has difficulty in breaking it. The writer has built a 24 in. valve of this kind for £5.

Plateau,
Kenya.

Yours, etc.,
W. L. JACKSON.

AN INTERMEDIATE HOST OF THE COMMON STOMACH FLUKE, PARAMPHISTOMUM CERVI (SCHRANK), IN KENYA

By J. A. Dinnik, East African Veterinary Research Organization, Kenya

(*Received for publication on 24th November*, 1950)

In Kenya, cattle are often infected with stomach flukes which are sometimes found attached to the inner surface of the fore-stomachs in thousands. A preliminary survey of the stomachs of 220 cattle slaughtered at the Nairobi abattoir has shown that at least five species of flukes occur in the stomach of Kenya cattle. These species are *Paramphistomum cervi* (Schrank, 1790), *Paramphistomum explanatum* (Creplin, 1847), *Cotylophoron cotylophorum* (Fischoeder, 1901), *Carmyerius exoporus* (Mapleston, 1923), and *Carmyerius* sp.

The most common is *Paramphistomum cervi* which is widespread among cattle, sheep and goats throughout Kenya. This fluke was found in 126 of the 220 cattle examined. *Cotylophoron cotylophorum* is also a frequent parasite in the livestock of Kenya but is less common than the first species. The three other species, *Paramphistomum explanatum, Carmyerius exoporus* and *Carmyerius* sp. were found only occasionally, although a few cases of heavy infection with both *Carmyerius* species were encountered in cattle from Naivasha and Nanyuki.

The adult stage of *P. cervi,* when the flukes have settled down in the rumen and reticulum is practically nonpathogenic. However, the immature parasites, which occur in the small intestines before migrating into the fore-stomachs, may be pathogenic to cattle and sheep. In heavy infections the young parasites cause severe irritation of the intestinal mucosa, resulting in hæmorrhage into the intestinal lumen and diarrhoea. Such infections may terminate in death brought about mainly by exhaustion due to the diarrhoea.

Experiments were carried out in this laboratory to ascertain which snails serve as intermediate hosts for *P. cervi* in Kenya. The snails used in these experiments were reared in the laboratory from eggs laid by the snails of the following species, collected from their natural habitats: *Bulinus syngenes* (Preston), from Lake Naivasha; *Bulinus alluaudi* (Dautzenberg), from Stony Athi River, ditches at Ruiru and from vleis at Limuru; *Biomphalaria pfeifferi* (Krauss), from Stony Athi River, and ditches at Kabete and Ruiru; and *Lymnæa caillaudi* Bgt., from Stony Athi River and ditches at Ruiru.

The eggs of *P. cervi* were obtained from adult flakes collected from the rumen of cattle slaughtered at the abattoir. They were incubated in tap water until the miracidia hatched. For experimental infection the snails were placed in a glass dish containing water to which numerous freshly hatched miracidia were added. After being left in the dish for three hours the snails were transferred into an aquarium where they were kept under observation.

A detailed account of the experiments is given in the Table.

Of the four species of snails used in the experiments only *Bulinus syngenes* (Preston) and *Bulinus alluaudi* (Dautzenberg), were successfully infected with the larval stages of *P. cervi.**

It appears that *Bulinus alluaudi* may be the principal intermediate host of the common stomach fluke in Kenya. This snail is often abundant in small streams or ditches containing running water, is not infrequently found in the pools remaining in dried up river beds, and sometimes occurs in shallow grassy pans which become flooded and marshy in the wet season, but are dry during the remainder of the year. (*See* Fig. 1.)

It was observed that in our experiments the period of development of the larval stages of *P. cervi* varied from 48 to 76 days. This variation was, no doubt, due to a number of factors, one of which appeared to be temperature. The period of development was considerably longer in the first and second experiments, in which the temperature fluctuated between 55° and 71° F., than that in the fourth, fifth and sixth experiments when the temperature was maintained at about 80° F. for the development of the fluke eggs and at between 72° and

* The snails, *Bulinus syngenes* (Preston, 1913) and *Bulinus alluaudi* (Dautzenberg, 1908), used in the experiments were identified by Prof. J. Bequaert, Museum of Comparative Zoology, Harvard College, U.S.A.

83° F. for the infected snails in aquariums. Temperature also appears to be an important environmental factor in influencing the escape of cercariæ from the infected snails. In cold water these did not shed cercariæ, but when the snails were placed under the rays of the sun or a strong electric light bulb which warmed the water, shedding of cercariæ began within half an hour.

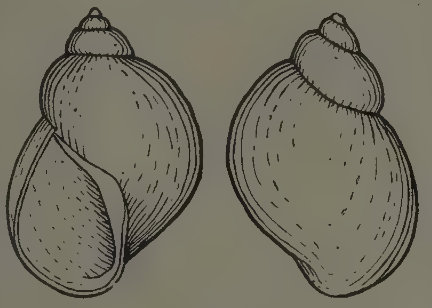

FIG. 1

Shell of *Bulinus alluaudi* (Dautzenberg, 1908) from ditches at Ruiru, Kenya.

Some of the experimentally infected snails shed more than 400 cercariæ in a single day but in the ensuing days the number of cercariæ shed was reduced to tens. After several days of rest in the aquarium the infected snails regained their ability to shed numerous cercariæ again. The period during which an infected snail can shed cercariæ appears to be very long, for in our first experimental infection the *B. syngenes* first shed cercariæ on 5th July, 1950, and have continued to shed them in considerable numbers up to the time of writing this article on 21st November, 1950.

After escaping from the snail, the cercariæ swam about quite actively and then congregated near the surface of the water where they encysted within half an hour. Encystment occurred on the walls of the glass vessel or on vegetation at the water surface.

The cysts of *P. cervi* are about 0.23 mm. in diameter and are easily discernible with the naked eye as round black spots. Cattle and sheep become infected with *Paramphistomum cervi* by swallowing these cysts, the stock ingesting them under field conditions when drinking or when feeding on vegetation carrying cysts in localities where infected *Bulinus* occur. In their turn the snails become infected with the larval stages of *P. cervi* by miracidia, which hatch from eggs passed in fæces of infected cattle.

I wish to acknowledge my indebtedness to the management of the Nairobi abattoir for the facilities afforded in examining cattle and collecting parasites.

Results of experimental infection of snails with miracidia of *Paramphistomum cervi* (Schrank).

Number of the experiment	Place of origin of cattle and date of collection of fluke eggs	Duration of development of miracidia	Species of snails used in the experiments	Date of the infection of snails	Date of first shedding of cercariæ	Duration of development of cercariæ in the snails	Species of snail which became infected
		days				days	
1	Naivasha 23–3–50	28	*Bulinus syngenes.* *Biomphalaria pfeifferi.* *Lymnæa caillaudi.*	20–4–50	5–7–50	76	*Bulinus syngenes.*
2	Naivasha 10–6–50	16	*Bulinus syngenes.* *Biomphalaria pfeifferi.*	26–6–50	24–8–50	59	*Bulinus syngenes.*
3	Nanyuki 7–7–50	15	*Bulinus alluaudi.* *Bulinus syngenes.* *Lymnæa caillaudi.*	22–7–50	15–9–50	55	*Bulinus alluaudi.* *Bulinus syngenes.*
4	Nanyuki 7–7–50	19	*Bulinus alluaudi.* *Bulinus syngenes.* *Biomphalaria pfeifferi.*	26–7–50	15–9–50	51	*Bulinus alluaudi.* *Bulinus syngenes.*
5	Nanyuki 9–8–50	15	*Bulinus alluaudi.* *Bulinus syngenes.* *Biomphalaria pfeifferi.*	24–8–50	16–10–50	53	*Bulinus alluaudi.* *Bulinus syngenes.*
6	Nanyuki 24–8–50	12	*Bulinus alluaudi.* *Bulinus syngenes.* *Biomphalaria pfeifferi.* *Lymnæa caillaudi.*	5–9–50	26–10–50	51	*Bulinus alluaudi.* *Bulinus syngenes.*
7	Ruiru 13–9–50	14	*Bulinus alluaudi.* *Biomphalaria pfeifferi.*	27–9–50	14–11–50	48	*Bulinus alluaudi.*

THE OIL PALM IN WESTERN TANGANYIKA

By D. Shepstone, Department of Agriculture, Tanganyika Territory

(*Received for publication on 9th November, 1950*)

Oil palms were first imported into the Kigoma region from the Congo many years ago, reputedly during a war between a sultan of Ujiji and a sultan from the Congo. Many importations have been made since then, mainly by Congo natives settling in the Kigoma area.

The seed has been spread by birds and pigs, and oil palms are now found growing profusely in the Ruanda and other areas of Kigoma and along the Tanganyika lake shore. Large plantings were made during 1937-1940 in the Kigoma district, particularly in the Mwandiga area.

During 1949 an oil palm count was made in Kigoma and along the lake shore, producing the following figures:—

	1 *to* 5 *years old*	*Over* 5 *years*	*Total palms*
Kigoma district ..	67,612	85,620	153,232
Kasulu district ..	4,028	3,185	7,213
Sumbawanga lake shore	1,873	5,042	6,915
Mpanda lake shore	—	1,500	1,500
		Grand total	168,860

It is estimated that 25 per cent of this total are bearing palms.

Distribution.—Oil palms are found mostly in a strip up to 12 miles wide along the shores of Lake Tanganyika from Kasanga in Ufipa district to Nyanza in Urundi. The majority of the palms are, however, found in the Ruanda (Luiche River valley delta) and in the Mwandiga and Ujiji areas. Palms planted at Makere in the Kasulu district at an altitude of 3,500 feet above sea level are now bearing heavily after 15 years' growth and recent pruning.

Climate.—Oil palms thrive in a rainfall of from 30 to 40 inches annually and an altitude of 2,500 feet above sea level and temperature of 81.2° F. maximum and 66.8° F. minimum. Palms are found growing at an altitude of 4,500 feet in Kasulu quite successfully, but above an altitude of 5,000 feet growth is retarded and yields very poor; in most cases the fruit will not ripen. It is thought that the ideal altitude is between 2,000 and 4,000 feet where rainfall is sufficient.

Soils.—Palms thrive in the river valleys on the well-drained alluvial soils and on the black and red loams and are also found in sandy soils.

Varieties

There are three distinct varieties, the thick-shelled nut, the thin-shelled nut and the green-fruited variety.

Vuma. (*E. guineensis var. dura*) or "Deli", named "Okporo" in Nigeria. The fruit before ripening is dark purple, almost black; when ripe the stalk end changes to red, the remainder being black or purple. The average fruit length is 40.9 mm. and the breadth 30.8 mm. The pericarp is relatively thin (3.4 mm.) and the shell is thick (3.2 mm). The kernel has a slightly rancid taste.

Vuma Jiwe.—This variety is practically the same as "Vuma" except that the fruit is longer, being 48.0 mm. and the breadth 30.0 mm., and the pericarp thinner (2.9 mm.). The kernel is smaller and the shell very hard and thick (3.4 mm.), hence the name "Jiwe" (stone). The colour is the same as "Vuma".

Bengeza. (*E. guineensis var. virescens*).—Called "Afia Oku" in Nigeria. The fruit is dark green before ripening, and when ripe is bright orange red, the tip retaining a green tint. Of this variety there are two types, the thick-shelled "Bengeza Vuma" and the thin-shelled "Bengeza Hote" which is the heavier yielder of pericarp oil. The fruits of these are more rounded than other varieties. "Bengeza Hote" has practically round fruit and kernels.

Hote. (*E. guineensis var. tenera*).—A thin-shelled nut called "Osok" in Nigeria. The fruit is 49.3 mm. in length and 29.6 mm. in breadth. The pericarp is very thick (5.1 mm.) and has a high oil content. The shell is thin (1.1 mm.). The kernel is round. The fruit when unripe is purple, and when ripe, yellow to orange-red with a mauve tint in the distal third of the fruit.

The following table shows the characteristics of each variety:—

TABLE

An average of 10 fruits taken at random	Hote	Vuma	Vuma Jiwe	Bengeza Hote	Bengeza Vuma
Average fruit length	49·3 mm.	40·9 mm.	48·0 mm.	44·0 mm.	45·1 mm.
Average fruit breadth	29·6 mm.	30·8 mm.	30·0 mm.	26·4 mm.	34·9 mm.
Average pericarp thickness	5·1 mm.	3·4 mm.	2·9 mm.	4·4 mm.	3·6 mm.
Average nut length	28·5 mm.	31·4 mm.	38·5 mm.	21·9 mm.	35·9 mm.
Average nut breadth	18·9 mm.	24·2 mm.	24·2 mm.	17·4 mm.	28·5 mm.
Average shell thickness	1·1 mm.	3·2 mm.	3·4 mm.	1·1 mm.	5·4 mm.
Average kernel length	18·9 mm.	19·1 mm.	23·3 mm.	14·0 mm.	18·5 mm.
Average kernel breadth	15·6 mm.	13·6 mm.	14·5 mm.	12·2 mm.	15·5 mm.
Total kernel weight of 10 fruits	·75 oz.	·75 oz.	1·00 oz.	·50 oz.	·75 oz.
Total shell weight of 10 fruits	·75 oz.	1·85 oz.	2·50 oz.	·50 oz.	4·00 oz.
Percentage kernel weight	50%	29%	29%	50%	15%
Percentage shell weight	50%	71%	71%	50%	85%

Methods of propagation.—Young palms are usually found self-seeded below the mother palm or are propagated by birds or pigs dropping the seed after eating away the pericarp. Very few seeds are sown by hand, young palms being mainly transplanted when needed from where they were self-seeded.

Seedbeds and planting.—Seed should be selected from ripe fruits and planted either in the pericarp or after its removal, the percentage germination is higher if the pericarp is removed. The fruit should not be boiled to remove the pericarp as this prevents germination.

The seed should be planted when fresh, and it takes two to three months to germinate and is ready for transplanting when six to 12 months old, or from one to three feet high. Light shade is advisable during the early stages, but once the seedlings are established, the shade should be removed. Young palms should be planted 30 x 30 feet apart, triangular spacing in the field (55 palms per acre).

In preparing seedbeds, it is advisable to use sandy soil, or mix sand with the soil. Compost will help to stimulate growth. Seeds should be spaced four inches apart and the rows one foot apart. The seeds should be sown one to two inches deep and watered morning and evening. When the plants are six inches to nine inches high they should be thinned out to 1 ft. x 1 ft.; this simplifies cultivation and the uprooted plants can be planted 1 ft. x 1 ft. apart in a nursery. When they are 1 ft. to 2 ft. high, the plants are ready to be moved to the plantation. Once the plants have been planted 30 ft. × 30 ft. apart in the field, it is advisable to interplant crops to repay cultivation costs as the ground must be kept clear of weeds. Interplanted crops can be grown successfully for the first five years.

Inflorescences.—The flowering of the oil palm is not fully understood. It appears to vary from one tree to another and during the life cycle of any one tree. Some trees bear only male inflorescences while others have the male and female flowers on one inflorescence, but this is rare. Some have male and female inflorescences growing in the axils of separate leaves. Others again have male and female inflorescences growing in the axil of one leaf.

It is said by the natives that certain trees bearing only male inflorescences may suddenly begin bearing female inflorescences in addition. It was noticed on these palms that there were separate inflorescences, i.e. male and female, where previously it was stated to bear only male inflorescences.

Fruiting and yield.—Young palms begin to bear from their third to their sixth year depending on the cultivation received and soil types, and are known to bear up to 50 years of age. The peak period of fruiting appears to be between the tenth and twentieth year. Although palms bear and ripen the whole year round, the peak ripening month is either September or October, varying with weather conditions.

One good tree of the variety "Hote" was seen with six large bunches, one of which weighed 70 lb. and bore 1,870 fruits weighing 36 lb. The average return per year from the palm oil and kernels of the variety "Hote" is Sh. 19/56 per palm, while other varieties have a lower average of Sh. 11/26 per palm. An average of Sh. 15 per bearing palm (all varieties) over the district is considered a reasonable figure. This gives a return of £40 per annum at 55 trees per acre.

Pruning.—No methodical pruning is done by the native growers. On ripening, a bunch is chopped off with a cutlass or axe and a few

lower fronds hacked away to make work easier. In certain areas where no pruning or methodical cultivation had been undertaken and where palms were barren, pruning and cultivation had the almost immediate effect of bringing the majority of the palms into bearing.

Palms that are badly affected by aphis or scale and are non-bearing are treated by the natives by lighting a fire around the bole below the fruit level; this treatment is said to bring the trees into bearing.

Preparation of pericarp oil ("Mawese").—The method of extraction is known as "the soft oil process". The bunch on ripening is cut and put aside for two days to ripen completely, the fruit is then chopped off with an axe or cutlass and put into a kerosene tin or clay pot; a little water is added and then it is boiled. When the fruits have softened, they are then put into a wooden mortar ("Kinu") and pounded. The pounded mass is then taken by the handful and rubbed out under cold water in a canoe-shaped trough. This rubbing removes the nuts and most of the oil from the fibre which is then put aside for re-cooking. This process continues until all the pounded mass has had the nuts and oil rubbed out. The oil floating on top of the water is then skimmed off by hand into a receptacle.

The fibre is boiled again and undergoes the same process, after which it is used for lighting the domestic fire. The oil, after being skimmed off the water, is then boiled, the oil is then decanted off the water and foreign matter which lies below. The nuts are put out to dry and later cracked by hand on a stone to extract the kernel, after which the kernels ("Mise") are marketed at a price of 29 cents per kilogram. The palm oil is sold at Sh. 1/50 per kilogram but is mainly used by the people themselves for cooking.

The pericarp oil ("Mawese") is bright orange or red and is used largely as a cooking oil or added to foods for flavouring. Very little kernel oil is extracted or used by the natives. There is much room for improvement in the methods of extraction and boiling down of the oil to avoid high acid content and to improve taste and colour. Machinery would give a higher extraction of oil of better quality than the native method.

Uses of the oil palm.—The oil palm has other uses besides the extraction of palm oil and the sale of kernels. The palm fronds are used as fuel, the green leaves are used for making receptacles or baskets for carrying loads, the fibre or the stem near the fronds is used for making twine for fishermen, and the old and barren palms are felled for extracting sap for making palm wine or toddy.

The fishermen use the palm oil to rub into the cotton used in caulking their boats. The dry fronds can be used for thatching where grass is not obtainable.

Making of palm wine ("Malovu").—To obtain "Malovu" the palm is chopped off at the roots and allowed to lie for a week, the top is then severed at the base of the young fronds. The remaining fronds are cut back on the trunk for about three feet and the fibre pulled off until the young white fibre shows. A distance of two feet is peeled back in this way in order to make tying easier. After the top is severed, the sap commences to drip and this increases after a few hours, or sometimes does not commence till 24 hours afterwards. A clay pot is inserted below the drip and palm fibre is tied from the pot to the severed end of the palm to exclude insects. Before the pot is tied on, resin ("Kasuku") is melted into the bottom of the pot. The resin is regarded by the natives as starting fermentation or souring the sweet sap. (There are conflicting opinions on the subject.) Every morning the cut palms are visited and the sap removed, a new cut of half an inch is made to encourage bleeding, and the pots re-tied. Bleeding on an old palm takes about ten to 15 days, and on a young palm from 20 to 30 days. Only the top end of the palm is cut and bled. The palm wine is ready for drinking (i.e. fermented) 12 hours after extraction.

Young palms of seven years old, when cut and tapped, yielded an average of 25 bottles of palm wine and 50-year-old palms yielded an average of 14 bottles. The price of palm wine is about 25 cents per bottle, therefore the palm wine from a tree of seven years old would be worth Sh. 6/25 and a palm of 50 years old Sh. 3/50. The yield of palm wine depends very much on the age of the palm and the soil and moisture conditions. Palms in the moist Ruanda valley-bottom are said to produce as much as 50 bottles per palm when ten to 20 years of age.

The palm sap also makes an excellent syrup or sugar when boiled with a taste similar to "butterscotch". The palm sap is distilled on the coast and is called "arrack" which is very potent.

In order to control the felling of palms, a felling permit is issued by the Agricultural

Instructor-in-charge. The person is shown the palms to cut, usually where thinning is necessary or barren or old palms. The person concerned then pays Sh. 2 per palm to the Native Treasury and obtains a receipt. This method is working satisfactorily as Agricultural Instructors can at any time discover any illicit felling.

Exports.—Prior to 1946, the marketing of palm kernels was unorganized and not more than five tons left the Kigoma district in any one year. During 1946 an effort was made by the Agricultural Department to establish a market and obtain a regular buyer. Ten tons of palm kernels were marketed in 1946 and increased to 192 tons in 1947 when the original buyer was granted a monopoly.

In 1948 the price to the grower was raised by a few cents per kilogram and 263 tons were exported during the year. The year 1949 saw an increase in price to the grower of three cents per kilogram, but owing to a severe drought early in the season, followed by heavy floodings of the Ruanda, only 240 tons were exported.

The export of palm oil was 12 tons in 1948 and 26 tons in 1949, these low export figures were due to the low price of 95 cents per kilogram. The export shows a remarkable increase since the price was raised to Sh. 1/50 per kilogram. The cash value of palm products during 1949 was:—

Palm kernels exported	Sh. 63,950	Total Sh. 102,400
Palm oil exported ..	Sh. 38,450	
Palm wine consumed locally	Sh. 170,000	Estimate
Palm oil consumed locally	Sh. 480,000	
Revenue to Native Treasury for felling permits ..	Sh. 6,800	

PESTS

Oryctes Monoceros, ol

This beetle is called "Dudu Faru" by the natives owing to the protuding horn similar to that of a rhinoceros. The beetle is causing a lot of damage to the oil palms by boring into the trunk of the tree causing its death. It appears to breed in felled palms, fronds and decaying matter.

Rhynchophorus phœnicis, F. (Palm Weevil)

This weevil is called "Dudu Tembo" by the natives because of its long proboscis. This insect bores into the trunk of the palm which it eventually kills.

Dyrastid—Beetle (identification pending)

It appears that this beetle is harmful to the oil palm, and its activity is being carefully watched and recorded. Observers state that it also bores into the frond of the oil palm.

Diaspine Scale, Fiorinia sp.

This scale is very much in evidence on the palm fronds and fruit and causes withering of the fruit.

Aphis

A white Aphis is found on the fruit which causes the bunch to wither and rot.

Analysis of palm oil

A sample of palm oil sent for analysis to the Government Chemist contained 400 mu./gm. of Carotene and had an acid value of 10.7. The Government Chemist states in his analysis, "The palm oil might contain vitamins of the B group. We have estimated the amount of aneurin or vitamin B.1 and find to be 1.2 mu./gm.".

Improvement of the industry

There is much that can be done to improve the palm oil industry such as: cultivation and pruning, thinning out and culling, seed selection and the planting of the best variety. The allocation of ownerless palms, and the burning or burying of dead palms and decaying matter to destroy breeding places of insect pests; also the extraction of palm sugar or syrup.

The erection of machinery to improve the grade and increase the quantity of oil, by the use of machinery for the cracking of nuts, and extraction of kernel oil for export to save shipping space. The roughage could be made into oil cakes and utilized as stock food or fertilizer to be used in the country.

There are very large unoccupied areas suitable for the oil palm in the Kigoma district and these could be utilized by European farmers.

Large occupied areas along the lake shore could be planted up to oil palms and natives could be encouraged to farm them, they should be fostered by establishing nurseries for plant distribution and later by establishing markets for the purchase of the palm oil and kernels.

ACKNOWLEDGMENTS

I wish to express my indebtedness to the Provincial Agricultural Officer, Mr. M. Lunan, B.Sc., A.I.C.T.A., for his helpful advice and criticism, to Mr. G. Swaine, B.Sc., Entomologist, for his help in identification of specimens, to the Government Chemist for his analysis of the palm oil, and to my Head African Agricultural Instructor, Mr. Aloys Kiozya for gathering data and information which often was done in his spare time.

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A NOTE ON WHITE BORER OF COFFEE

By F. B. Notley and R. G. Tapley, Entomologists, Department of Agriculture, Tanganyika Territory

(*Received for publication on 5th September*, 1950)

In the course of work on the White Borer of coffee, *Anthores leuconotus* Pasc, experiments were laid down on the control of the adult. It was thought that since the flight period of the adult is restricted to a few months during the long and short rains, and since the adult feeds on leaves and the bark of twigs (Knight, 1939) an insecticide which could be applied at the beginning of the rains and possessed sufficiently good sticking properties might kill a large enough proportion of adults to reduce the number of eggs laid. A preliminary experiment laid down in the short rains of 1948 showed some promise for the method, using Paris Green as the insecticide: D.D.T. appeared to give no control. An experiment on more precise lines was laid down in March, 1950. The treatments applied were: Paris Green with Bordeaux, Paris Green with lime casein, and control, untreated. The amounts applied were the equivalent of 3 lb. Paris Green per acre, with 1 per cent Bordeaux, and with 3 lb. Lime casein per acre. Each treatment was repeated three times, and each plot consisted of 100 trees. The coffee on which this experiment was laid down was very heavily infested with borer, later counts showing an average of 11 borers per tree.

When observation showed, at the end of July, that all the new generation of eggs had hatched, 40 trees from each treatment were uprooted and the young larvæ dissected out in the laboratory. No trees were selected for uprooting from the outside two rows of each plot, which thus served as guard rows; otherwise trees uprooted were selected at random.

Paris Green with Bordeaux showed no reduction in the number of young larvæ over the control, but Paris Green with Lime casein showed a reduction of 37 per cent, which was statistically significant.

Whilst the reduction achieved was not great, it does indicate that further work on these lines might yield results of value.

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TABLE

Plots	No. of trees	Degrees of Freedom	Mean No. of larvæ per tree	Square of mean differences
Paris Green + Lime casein	40	39	2·425	429·79
Control	40	39	3·900	273·60
		Sum. 78	Diff. 1·475	Sum. 703·39

V=9·0178. S.E. of Difference=0·671. t=2·198. $P < \cdot 05$.

A NOTE ON ANTESTIA CONTROL WITH D.D.T. AND BORDEAUX MIXTURE

By F. B. Notley, Entomologist, Department of Agriculture, Tanganyika Territory

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In a previous article (Notley, 1949) methods of Antestia control which had been used at the Coffee Research Station, Lyamungu, were compared. Since then the use of D.D.T. emulsion has been the standard method, and the results over last year are of considerable interest.

The method previously in use was to spray any block which, on test spraying with pyrethrum extract, showed an infestation exceeding an average of 0.3 per tree. It is a standard practice to spray the coffee on the Station with Bordeaux mixture before and after the rains. For the last year, therefore, instead of treating plots individually we have added D.D.T. to this Bordeaux mixture as a routine. It will be seen from the figures in the Table that this change in practice has not in fact meant that infestations exceeding 0.3 per tree have remained unsprayed for any length of time, but it has meant that many plots with an infestation of less than this figure, or no infestation at all, have been sprayed.

The spray used is Bordeaux mixture, 1 per cent or one-half per cent, at 160 gallons per acre, to which is added 0.05 per cent D.D.T. Thus, though the amount of spray applied is double, the strength of D.D.T. is half, that of the recommended 80 gallons per acre of 0.1 per cent D.D.T., and the amount of D.D.T. applied per acre is the same. Home-made emulsion, using technical D.D.T., power paraffin, yellow soap and water was used.

The figures for test spraying are given in the Table. Only those plots which showed infestation in June—July, 1949, are given. Ten trees are tested in every plot, which gives an average over the whole Station of over six trees per acre test sprayed on each round.

The notable feature is the complete absence of Antestia from the time of spraying in July until December, and again its complete absence in July, 1950. This applies to all plots, including 37 not given in the Table, since they had no Antestia in July, 1949. Since no Antestia were

TABLE

Plot No.	1949						1950				
	June-July		July-Aug.	Aug.-Sept.	Oct.	Dec.	Jan.-Feb.	March		April	July
I	0·8	All plots sprayed with Bordeaux and D.D.T. in July 1949	0·0	0·0	0·0	0·0	0·0	0·3	All plots sprayed with Bordeaux and D.D.T. in March 1950	0·0	0·0
II Ls II	0·2		0·0	0·0	0·0	0·0	0·0	0·0		0·0	0·0
II Ls III	0·1		—	0·0	0·0	0·0	0·0	0·0		0·0	0·0
II RB II ..	0·3		0·0	0·0	0·0	0·0	0·1	0·7		0·0	0·0
III	0·4		0·0	0·0	0·0	0·0	0·0	0·0		0·0	0·0
III A	0·3		0·0	0·0	0·0	0·0	0·1	1·8		0·0	0·0
IV Ls II ..	0·1		0·0	0·0	0·0	0·0	0·0	0·1		0·0	0·0
V	0·6		0·0	0·0	0·0	0·0	0·0	0·7		0·0	0·0
VI	0·8		0·0	0·0	0·0	0·0	0·2	0·4		0·0	0·0
VII A	0·1		0·0	0·0	0·0	0·0	0·1	0·0		0·0	0·0
X	0·7		0·0	0·0	0·0	0·0	0·0	0·0		—	0·0
XI	0·7		0·0	0·0	0·0	0·0	0·0	0·0		—	0·0
XII	0·4		0·0	0·0	0·0	0·0	0·0	0·0		—	0·0
XIII C	0·3		0·0	0·0	0·0	0·0	0·0	0·2		0·0	0·0
XIV A	0·7		0·0	0·0	0·0	0·0	0·0	0·0		0·0	0·0
XVII	0·7		0·0	0·0	0·0	0·0	0·3	0·1		—	0·0
XVIII Ls I ..	0·3		0·0	0·0	0·0	0·0	0·2	0·1		0·0	0·0
XVIII Ls VIII ..	0·1		0·0	0·0	0·0	0·0	0·1	0·0		0·0	0·0
XVIII Ls XIII ..	0·1		0·0	0·0	0·0	0·0	0·0	0·5		0·2	0·0
USAGARA 28..	0·4		0·0	0·0	0·0	0·02	0·07	0·1		—	0·0
USAGARA 29..	0·9		0·0	0·0	—	0·03	0·02	0·12		—	0·0
V.G.	0·2		0·0	0·0	0·0	0·0	0·0	0·1		0·0	0·0
AMANI SEL. ..	0·1		0·0	0·0	0·0	0·0	—	—		0·0	0·0
Average ..	0·395		0·000	0·000	0·000	0·002	0·052	0·238		0·012	0·000

found in test spraying throughout the coffee in July, 1950, no D.D.T. was applied with the Bordeaux spray which was put on at this time.

There is an interesting point in that the Coffee Research Station is closely surrounded by other coffee, where control of Antestia is by no means so thorough as it is on the Station, yet the figures show that very little re-infestation takes place from outside. Further observations are obviously necessary, but the interest of these figures is in the suggestion they give that routine spraying with Bordeaux-D.D.T., carried out at the normal times for Bordeaux spraying, may be effective in a very short time in virtually eliminating Antestia from the coffee. It is true that even if Antestia is completely eliminated from the coffee, re-infestation will occur, either from adjacent coffee or from native host plants, but it has been shown (Taylor, 1945, and Michelmore, 1949) that such re-infestation will be slow, and it may be that the extra expenditure entailed in attempting elimination would be more than offset by a reasonably long period during which control measures may be unnecessary.

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BOOK REVIEW

BEEKEEPING, CRAFT AND HOBBY, By Cumming and Logan (Edinburgh, Oliver & Boyd, 1950). Price 10/6d.

"The beginner must always remember that hives are merely boxes to house bees, with varying degrees of comfort and suitability, and that the successful production of honey depends upon a good strain of bee and the understanding skill of the beekeeper."

This quotation is of no less significance to the East African beekeeper than to the British beekeeper for whom the book is written. Under tropical conditions it is probably even more definite that equipment, however desirable and pleasing to the eye, cannot make up for deficiencies on the part of either the bee or the beekeeper.

The East African bee has shortcomings as a honey producer. This is understandable when it is considered how it must struggle for survival in an endless battle with ants, beetles, birds, reptiles, honey-badgers and man, until ferocity has become an essential character and frequent swarming a necessary safeguard against extinction. In addition, the absence of a winter season for which a food reserve must be laid away removes the stimulus to accumulate large stores of honey, a trait which the beekeeper in temperate zones has developed to his own advantage.

The "understanding skill of the beekeeper", however, is more amenable to improvement than the temperament of the local bee. For the beginner "Beekeeping, Craft and Hobby" provides a useful introduction. Naturally in a book written by a former Hon. Secretary of the Inverness Beekeepers' Association and an assistant lecturer at the North of Scotland College of Agriculture there is some emphasis on heather honey production and the combating of hard winter weather. On the other hand the book is written for the small-scale beekeeper and the hobbyist and so omits much that concerns only the large commercial producer, who is not likely to come to East Africa. The style is agreeable, clear and free from the pedantic.

The authors provide a brief exposition of the life of the hive, including a summary of von Frisch's recent observations on the dance language of bees, before proceeding to discuss equipment and hive management. A glossary of "beekeepers' jargon" and a "synopsis of good beekeeping practice" will appeal to those who like to have their facts made readily available for reference. In the absence of a guide to tropical bee management, the beginner in East Africa must make his own adaptations of temperate practice to suit local conditions. This book provides a concise account of beekeeping in Scotland with sufficient explanation of the basic principles to provide the East African enthusiast with a good foundation.

W.V.H.

THE RECLAMATION OF SISAL FLUME TOW

By J. G. Thieme, Sisal Products (E.A.), Ltd., P.O. Ruiru, Kenya Colony

(Received for publication on 8th November, 1950)

As far back as 1923 the author was occupied in scientific investigation on the purification of waste water from a Java sisal factory through the means of digesting tanks and biological filters, trying at the same time to produce combustible gas from this water. The success of these experiments encouraged him to look also for a biological solution of the flume waste problem. After many fruitless efforts he found a few suitable retting processes, aerobic retting as well as water retting. The latter method gave the best product and was chosen for commercial practice and it became the solution for the flume waste problem of many a sisal estate in Java and Sumatra.

Commercial water retting was started on a small scale, without using machinery, on the sisal estate Djengkol in Java in 1924. In 1926, after developing the necessary machinery for handling great quantities of waste, a central retting plant was erected at Laras in Sumatra, which after several extensions produced flume tow from the waste of some forty decorticators; the production before the war was about 6,000 tons of retted flume tow annually, which found a ready market in the United States where it was used mainly for upholstery.

About 1930, an additional retting plant was installed at Bendoredjo in Java and the product was either exported or used for making sacks locally.

At the invitation of Sisal Products (E.A.), Limited, Ruiru, the author, since December 1948, has studied the flume waste problem of Kenya and has tried to find improved reclamation methods. It was realized that the retting process used in Java and Sumatra was not suitable for Kenya because of a limited water supply for retting purposes than what is available in the Indies; also temperatures are generally lower, so a new method had to be found.

For the mechanical treatment prior to and after retting new machinery had to be designed. It makes a difference whether machines have to deal with the waste of ten to forty decorticators as in Java or Sumatra or of only one or two as here. The new machinery had to be simple, robust, efficient and cheap in upkeep with a minimum of supervision.

In the first part of this paper a synopsis of the flume tow problem is given and existing reclamation methods will be discussed. The second part deals with sisal retting in general; various retting experiments and possible retting methods will be described, and lastly the third part gives a description of the new reclamation plant, developed by Messrs. Sisal Products as a result of these described experiments.

PART I

The Flume Waste Problem

Amount of Waste.—The decorticator extracts between 3 to 5 per cent of fibre from the leaf, the remainder becoming waste and discharged into the flume.

About two-thirds of this gross-waste consists of juice and small pieces of crushed fleshy matter, which is suspended or dissolved in the flume water; therefore only about one-third of the weight of the leaves can be reclaimed as proper flume waste, which is a soggy mixture of entangled fibres, fleshy matter and pieces of undecorticated leaf.

Loss of Fibre in the Waste.—The flume waste contains a considerable percentage of fibres. There are two reasons why a certain loss of fibres is inevitable in decortication. One is, the peculiar distribution of the fibres in the leaf, the other being the imperfections of decortication machinery.

Agave leaf contains three different groups of fibres—

(*a*) long, thick fibres, forming the backbone of the leaf and running from the butt-end to the tip; only these central fibres have the same length as the leaf;

(*b*) thinner fibres of various lengths embedded in the white fleshy matter of the leaf, all starting at the butt-end but ending at various places between butt-end and tip;

(*c*) very thin fibres in the outer layer of the leaf, starting and ending somewhere between butt-end and tip.

The last group is of no significance, being of no value, and is always lost during decortication.

The long fibres (*a*) can readily be extracted as line fibre. As to the fibres (*b*), the main group, it depends on the place where the leaf is gripped by the rope or chain and on the more or less perfect working of the decorticator as to how many of them will be lost with the waste. Line fibre is, therefore, a mixture of the long fibres group (*a*) and part of the shorter fibres group (*b*); because of the structure of the leaf line fibre can never consist of fibres of uniform length.

Flume tow fibre comes from group (*b*) and group (*c*).

As all fibres group (*b*) start at the butt-end, the ideal decorticator should grip the leaf as near to the butt-end as possible. This is the principle of Corona No. IV. Experiments made by the author in Sumatra revealed that with this type of machine the fibre loss can be as low as 5 per cent.

Machines that decorticate the butt-end first grip the leaf at a certain distance from the butt-end and are bound to lose all fibres shorter than this distance. Experiments with Corona No. II showed that there exists an optimum distance for which the loss is a minimum and that this optimum distance varies with the length of the leaf. Theoretically this type of decorticator should give a higher loss than the type which grips near the butt-end.

In practice, however, the actual losses are much higher than in theory and are influenced by various factors: the setting of the drum, the tightening of the ropes, the way in which the concave has been worn, the feeding, the quality of the leaves and many others.

It is not possible to set a decorticator to establish good decortication for both long and short leaves. If several decorticators are available, the leaves should be divided in groups according to length, say long, medium and short, using a separate decorticator for each length group. In this manner and with decorticators properly set and in good condition, a loss of 12 to 15 per cent of the fibres is a reasonable and practicable result.

With only one decorticator being used continually for all types of leaves, the loss is bound to be much higher. In Kenya, where such is the case, a loss of 20 to 25 per cent of the fibres is more or less normal and with short and dry leaves it can even be higher.

It is certainly worth while, considering that an average estate in this country loses between a quarter and a fifth of all fibres in the leaf, to look for ways and means of reclaiming the fibres from this waste.

Composition of Flume Waste.—In addition to fibres, flume waste comprises the fleshy matter of the leaf and the cuticle. Part of the fleshy matter and the cuticle, torn to little pieces in the decorticator, are not connected with the fibres and can easily be separated by mechanical means. This part will be called the "loose pulp". The problem of reclaiming fibres from the waste would be an easy one if all the fleshy matter was present in the form of loose pulp.

This, however, is not the case and because part of the fleshy matter is still connected with the fibres ("adhering pulp") it is not easy to separate. The adhering pulp, therefore, becomes the crux of the problem.

Usually there will also be found pieces of undecorticated leaf in the waste, especially the hard edges of the leaf ("barky runners"), which become an additional difficulty.

Reclaiming of Flume Waste.—Except in the case of raspadors or the rather problematical dry decortication, the waste has first to be separated from the water used for decortication. If the decorticator is placed on a high platform, trolleys can be placed under the machine, allowing the waste to fall directly into the trolleys and the water to drip out. This method of reclaiming the waste sounds very simple but is only so in theory. In practice it gives a lot of trouble; the work under the machine is unpleasant, and because of the high acidity of the flume water the trolleys are expensive in upkeep.

The method generally adopted is, first to let the waste fall into a water channel, to flume it to the reclamation plant and to fish it out by some mechanical device. The advantages of this system are: cheap transport to the place for treatment, saving of labour and—above all—removal of parts of the acids and loose pulp, which remain in the flume water.

The lifting of the lumps of waste out of the water causes no serious problem. If the reclamation plant is at a lower level than the main factory, the simplest solution is a conveyor on which the water with the waste falls. In other cases the waste can be fished out by forks fixed on chains or dragged out by scrappers on an inclined plane.

A practical solution is the "collecting brattice" used in the old reclamation plant of Sisal Products and introduced about 1937.

Mechanical Separation of Loose Pulp.—The oldest and a very elementary way of securing flume tow was by shaking it out by hand in order to get rid of the fleshy matter, cuticles and barky runners. As only loose pulp responds to such treatment, the flume tow obtained in this way still contains a lot of adhering pulp and consequently is a dirty and indifferent product. Also it is difficult to dry because of the particles of adhering fleshy matter; then again, if it is not washed before drying, the adhering acids can lead to discoloration, especially if the drying process is delayed.

The amount of loose pulp in wet flume waste is high, about 60 to 65 per cent. It will make subsequent operations easier and cheaper if the pulp is got rid of by a simple mechanical operation.

Shaking by hand requires a lot of labour and as a result many devices have been tried to do it mechanically. Of the various machines tried or used for this purpose the following three main types can be distinguished:—

(1) *Flat Screens.*—The principle is a flat, inclined screen that by some mechanical device (eccentric, crank shaft, etc.) receives rapid blows, which constantly dislodge the material. All kinds of constructions and combinations are known; the vibration can be a "positive circle throw" motion or a reciprocating motion.

Flat screens of various constructions play a great role in tea, sugar, and starch factories, are used for classifying minerals ("jigging screens") and various other purposes. They are very efficient for hard materials.

However, with a soft, elastic and cloggy material like flume waste the result is disappointing; it can be said that generally the principle of the vibrating flat screen is not the solution for this type of raw material.

(2) *Tow-shaker.*—In the old tow-shaker of Sisal Products the waste was shaken out by vigorously moving pins combined with a double belt to carry away the pulp, the pins being placed at an angle to permit of shaking and transporting the waste at the same time.

The working of this machine was far from being ideal. In recent experiments it was found that only 12 to 15 per cent of the weight of the waste was shaken out as loose pulp. Besides, the rapidly moving pins gave a lot of mechanical trouble and are expensive in upkeep.

(3) *Revolving Cages.*—The solution seems to be a revolving cage, about 10 to 12 ft. long and 3½ to 4 ft. in diameter. The cage contains no shaft or other obstacle, being driven from the outside. The revolutions are of a certain relation to the diameter so that the material inside the cage neither rolls nor is pressed by centrifugal force against the iron rods, which form the cage and serve as a screen; the waste is periodically taken up and allowed to fall down again. The same principle is used in revolving driers for sugar, cement and various other products.

Such a revolving cage is the "Pulp Separator", which after successful experiments was developed for the new reclamation plant in order to clean the waste mechanically before retting. It will be further described in Part III.

The efficiency of this pulp separator is very high; about 60 per cent of the weight of the waste falls out as loose pulp. The separator works automatically and is cheap in upkeep; it is a very simple machine which gives no trouble and needs practically no supervision.

For every type of mechanical shaker, whether flat screens, tow shakers or revolving cages, the waste has to be freed from part of its water-content first to avoid clogging-up of wet pulp. This can be done in a simple way by passing the waste through a squeezer. The squeezer of Petrie and McNaught has been found very satisfactory for this purpose, but any other type of construction, even home-made squeezers, will do.

Mechanical Separation of Adhering Pulp.—Up to the stage of separating the loose pulp, the reclamation of flume tow presents no major difficulty. Problems arise, however, when it is tried to get rid of the adhering pulp, which is firmly attached to the fibres.

Quite a lot of research has been devoted in the course of the years, in East Africa and elsewhere, to the problem of separating fibres and adhering pulp by mechanical means. That the problem is not insoluble is proved by the decorticators, which, after all, do the same job. But the decorticator principle cannot be used for the purpose because the fibres in the waste are all entangled.

Two main principles can be distinguished, which in one or other form can always be found in machines designed for this purpose: crushing the fleshy matter by pressure between rollers in order to loosen the contact between fibre and pulp, and tearing the fleshy matter

off by pinned drums in a more or less primitive wet-carding process.

(1) *Crushing Rollers.*—It is easy to crush an isolated piece of fleshy matter between rollers; it is even possible to "decorticate" a leaf in this way, and a special decorticating process was based on this principle by McCray in 1936.

However, in a lump of flume waste the pieces of fleshy matter are not isolated but embedded between entangled fibres. If this entangled mass is sent through the crushing rollers, most of the pieces of fleshy matter are not crushed at all. The reason is that the mass of entangled fibres has a certain elasticity and protects the pieces of fleshy matter like a cushion against getting the full pressure.

To achieve something with rollers, two conditions have to be fulfilled: the flume waste must be fed into the rollers in a thin layer and the pressure must be high. Experience has shown that in practice the first condition is very difficult to fulfil and that the application of high pressures implies the danger of damaging the fibres.

Crushing rollers formed part of the old reclamation plant of Sisal Products ("Rutherfoord-rollers"); everybody who has worked with these rollers knows that the effect was disappointing.

(2) *Pinned Drums.*—A better cleaning effect is achieved by the carding principle, tearing off the fleshy matter by pinned drums. But at the same time the risk of damaging the fibres is much higher.

Carding of entangled fibres, even if the fibres are free of adhering pulp and the card is a perfect and carefully set instrument, will always do a certain amount of damage to the fibres, especially shortening the longer fibres. The damage is greater if the card is only a primitive instrument like a so-called estate-card or even a home-made pinned roller. But the biggest damage is and must unavoidably be done if the fibres are not only entangled but partially fixed together by pieces of fleshy matter.

There are not only "free" fibres with only some pieces of fleshy matter sticking to them, but there are many bundles of fibres, kept together by a particle of pulp. It is unnecessary to explain that such a "nest" cannot be cleaned without tearing some of the fibres to pieces. Other fibres are not actually torn up but only damaged. This damage can be shown if one tries to bend such a fibre: at the place of damage it does not bend but forms a sharp angle. If this fibre is later on exposed to heavy strain during spinning and weaving, it will break at the point where it has been damaged.

The total effect of shortening the fibres by treatment with pinned rollers cannot easily be appreciated visually. An exact method of measuring the "average length" of the fibres in flume tow is needed. The author developed such a method (to be published later), tested with it, since May, 1949, many hundreds of samples of flume tow from various estates and studied the influence of carding and other treatments. Some of the conclusions that may be of interest in this connexion will be given in a following paragraph.

In general it can be said that flume tow prepared by a purely mechanical process, using pinned rollers or similar devices, can be (but is not always) a rather clean product; but the cleaner the tow, the more the fibres are damaged. Such a tow is, therefore, not the most suitable material for spinning purposes.

There may be other markets for such a tow, where length does not matter so much, for example as a raw material for upholstery. This is not only a technical question but depends also on price and general market position. Quality matters less in times of shortage of raw materials and high prices, but can make all the difference in a buyers' market and against strong competition. Years before the war, Java produced for some time a type of unretted flume tow, which was no longer saleable when the retted tow appeared on the market. The American buyers of flume tow for upholstery preferred in the years when there was ample choice the retted product.

Efficiency machinery for preparing flume tow by a wet-carding process will be expensive in capital outlay and upkeep. It may solve the flume tow problem to a certain extent, but this solution will neither be the best nor the cheapest.

Length-composition of Flume Tow.—Flume tow is composed of fibres of all lengths from one inch up to a certain maximum length that varies between 20 and 30 inches; it contains these fibres in varying percentages.

For practical reasons the fibres are divided in length-groups of four inches; the first length-group consists of fibres from 0-4 in., the second

from 4-8 in. and so on. The length-composition of a certain sample of tow is shown by its staple-diagram; it gives for every length-group the percentage of the weight of fibres.

As an example are given here the staple-diagrams of a rather short and a rather long flume tow; most flume tows are somewhere between these extremes.

Sample	Percentage of fibre weight between:							
	Inches 0–4 %	Inches 4–8 %	Inches 8–12 %	Inches 12–16 %	Inches 16–20 %	Inches 20–24 %	Inches 24–28 %	Inches 28–32 %
Long tow	10·8	20·3	32·9	12·6	8·3	9·0	5·4	0·6
Short tow ..	45·5	46·5	7·4	0·6	—	—	—	—

By multiplying the percentage in each group with the length of the group, adding together and dividing by a hundred, the "average length" of the flume tow is obtained. Samples of the same average length need not have the same staple-diagram, but their staple-diagrams differ only within certain limits. For most purposes it is, therefore, sufficient to know the average length of a sample.

A quick method has been found to determine this average length directly, independent of the staple-diagram.

The two samples of long and short tow above have average lengths of 13.3 in. and 6.6 in. During 1949, 215 samples of flume tow were tested from 35 different sisal estates. They had, all together, an average length of 10.6 in. The longest individual sample was 19.8 in. and the shortest 6.6 in.; the longest estate-average was 13.1 in. and the shortest 6.6 in.

Grouped according to decorticators, Raspadors had an average of 11.7 in., Robeys of 9.5 in. and Coronas and Storks together of 8.8 in.

The maximum length of fibres in flume tow is in a certain relation to the average length; it is about 20 in. for an average length of 6.5 in. and goes up to about 31 in. for an average length of 13.5 in.

Carding with a perfectly set teazer card reduces the average length to a certain extent, depending on the original length. The length-reduction varies as an average from about 5 per cent for very short to about 30 per cent for very long flume tow.

However, there are differences in behaviour during carding for various types of flume tow. By comparing the actual length-reduction with the average length-reduction for the same original length, it can be found whether a flume tow is more or less than normally damaged by carding. Weakened, deteriorated or damaged fibre is more reduced in length than "healthy" fibre. Also flume tow that still contains adhering fleshy matter is more damaged by carding, showing at the same time a higher "carding loss".

Much more damage results when the flume tow is treated at the estate with a more or less primitive estate-card; estates that are known to treat their tow in this way come generally not higher than 6 in. to 7 in. average length. Such a carding operation gives the product a nicer appearance at the expense of the length; but it is a very bad method if the product has to be used for spinning.

Very short fibre is produced if the flume tow is prepared by a mechanical device that tears the fleshy matter from the fibres, as described in a previous paragraph. As an example may be mentioned a flume tow that was prepared in this way. It had a nice, clean appearance, but the average length was just above six inches and the staple-diagram showed more than 56 per cent in the group 0-4 in. and more than 35 per cent in the group 4-8 in. Such a product might find a market for special purposes but is unsuitable for efficient spinning.

It is self-evident that bad decortication will result in a longer, and good decortication in a shorter flume tow, if leaves of the same length are decorticated. It is also natural and in the interests of the East African Sisal Industry that every estate tries to achieve the best decortication and, therefore, to produce the shortest flume tow possible. Long fibres belong to the main product of line fibre and not to flume tow.

As long as flume tow retains its natural length and is not shortened by artificial means, it will be a suitable raw material for spinning. It is only against the unnecessary damage of fibres that it was thought necessary

to issue a word of warning in the matter of damage done by unsuitable reclamation machinery or by a superfluous finishing treatment in primitive cards.

Pulp-separation by Chemical Treatment.—As the separation of fibres and adhering pulp by purely mechanical means was considered not entirely satisfactory, chemical methods, either alone or in connexion with mechanical devices, have been tried but—as far as is known—never with commercial success.

From a chemical point of view the problem is to dissolve the pectin of the pulp without affecting the cellulose of the fibres. If entire dissolution is not possible, the pectin could be weakened by reactions that change its structure and properties, say by partial hydrolysis or by converting its calcium and magnesium salts of low solubility into sodium, potassium, or ammonium salts by means of ionic exchange.

For flax this type of "chemical retting" has been tried with alternative treatment using acids and alkalis at temperatures from 60° to 100° C. The acids used were hydrochloric, sulphuric, oxalic and oleic acid, the alkalis sodium hydroxide, sodium carbonate and ammonium hydroxide. The chemicals have to be used in low concentrations (about 0.02-0.1 normal) in order not to affect the fibres. Treating flax in an autoclave with neutral salts, phosphates, sulphates, oxalates and tartrates, has also been recommended. However, these processes are described as still in the experimental stage.

The extraction of sisal pectin has been studied by Sir John Ramsden and his collaborators and their discoveries form the subject of various patents of the African Sisal and Produce Company, Limited. The work was not done to reclaim the fibres but to win pectic substances as a commercial by-product. However, their conclusions as to the properties of sisal pectin are also of interest from a viewpoint of chemical retting.

One of these conclusions is (1) that pectin exists in the flesh of *agave sisalana* as a protopectin in combination with or as salts of calcium and magnesium. Pectin can be extracted by treatment with various acids, followed by an alkaline extraction of pectic salts.

Years before the war, the author made many experiments in Java, treating flume waste with various chemicals in order to find a substitute for biological retting. Of all the chemicals used, the best results were achieved either by alternative treatment with diluted acids and alkalis or by ammonium oxalate. From a fibre reclamation point of view, however, the results were rather disappointing; even by boiling the fleshy matter for hours with the reagents, the fleshy matter was neither completely dissolved nor sufficiently weakened to be removed by washing.

But even if the technical result had been better, the costs of such a treatment would be too high for a low-priced waste, which has a big volume compared with the weight of the dry fibre. One ton of dry flume tow represents in the form of flume waste a volume of 1,000 to 1,200 cu. ft.; it would require an expensive installation consisting of vessels for the treatment, a steam boiler with piping and appendages, devices for charging and discharging the vessels, tanks for dissolving the chemicals, etc. There would be running expenses for fuel and chemicals, which even in the case of low-priced chemicals like soda-ash would be considerable owing to the big volume of the raw material to be treated. Last, but not least, such a process would require European supervision and chemical control.

If we compare this with the simple new retting process as described in Part II, for which only a pump and a few sprinklers and not even tanks are required and which can be left to the care of an African, it is evident that a chemical treatment, even if technically successful, could never compete economically. It could only be considered if it had some extraordinary effect that could not be produced by other means.

Pulp-separation by Retting.—The best and at the same time cheapest method to dissolve or weaken the adhering pulp is retting. In a certain sense retting is also a chemical method: dissolving the pectin is achieved by an enzyme, a complicated chemical of more or less unknown structure. Enzymes have been compared with keys that open noiselessly and quickly the locked doors of the molecules whereas other chemicals clumsily break these doors open.

Retting is a very common and very old process of preparing flax, jute and other fibres. It is less common for sisal and a little more difficult, owing to the peculiar chemical composition of the sisal leaf.

The theoretical and practical aspects of sisal retting will be dealt with in Part II.

Washing of Retted Flume Tow.—For various reasons the retting process cannot be prolonged till all fleshy matter has been dissolved and only the fibre results. The process has to be broken off when most of the adhering pulp has been transformed into a slimy substance; then this substance has to be washed out.

If sufficient cheap labour is available, the washing can be done by hand, but for most of the estates it will be necessary to do it mechanically.

The problem of mechanical washing is not a difficult one and can be solved in various ways. For the big retting plants in Java and Sumatra three different types of washing machines were developed in the course of the years. None of them seemed to be the ideal solution for Kenya. What is wanted here is a simple, small and robust machine without fast-moving parts, which is cheap in upkeep and can be left to the care of an African.

It was, therefore, decided to develop a new type of washing machine for East Africa, consisting in principle of a long channel through which the flume tow is moved continuously by series of prongs against water in counter-current. No fresh water is needed for washing, but the water drained from the retting process is used. Before falling into the channel of the washing machine, the retted waste passes a squeezer to squeeze out part of the slimy matter and to open up bigger pieces of fleshy matter and barky runners.

Part II

Theory and Practice of Sisal Retting

Functions of Retting.—Retting is a strictly defined biochemical process: the decomposition of pectin by an enzyme, produced by certain bacteria or fungi.

This process does not affect the fibres but only the fleshy matter in which the fibres are embedded, making it soft and slimy and eventually dissolving it. After retting, it is easy to free the fibres from other parts of the plant, either by scutching as in the case of flax or by a single washing process as in the case of sisal.

Preparation of textile fibres by means of retting is one of the oldest technical processes known. It is generally used for flax and jute, but also for other fibre-plants.

Flax-retting has been the subject of scientific research by numerous investigators and there is a comprehensive literature on this subject. There is, however, practically no literature on sisal-retting; the work done in this line in Java between 1923 and 1926 and in Kenya between 1938 and 1940 was never made public, except in the form of an extract of the latter work, recently published in this Journal by Politzer [2]. It will, therefore, be necessary to refer to the scientific work done on flax as far as the theoretical aspects of retting are concerned.

Pectin.—The substance that is decomposed by retting is pectin, one of the three main building-materials of plants: cellulose, lignin and pectin. The middle lamella, by which the cell walls are joined to one another, consists mainly of pectin.

The structure of pectin is very complicated and only partially known. It is a complex compound, consisting of a number of polysaccharides. According to some investigators it contains a nucleus of tetragalacturonic acid, to which amongst other radicals more or less methyl-groups are fixed. Decomposition of this pectic complex would start with the gradually breaking away of the methyl-groups. This would explain why various products can result from gradual decomposition, varying in viscosity and solubility.

Pectin need not be present in the plant as such; it can be in combination with, or as, salts of certain metals. It is assumed that one of the differences between sisal pectin and, for example, apple or citrus pectin results from the fact that in sisal the pectin is combined with calcium and magnesium [1].

From a retting point of view, the word pectin can, therefore, better be substituted by "pectic substances". Experience with retting of various plants seems to indicate that the resistance against retting, and, therefore, probably the composition of the pectic complex, varies from plant to plant. For practical retting purposes it can be distinguished between "soft" and "hard" pectic substances. To the soft group belong potatoes, apples, flax and also sisal; to the hard group for example *musa textilis* (Manilla hemp) and the husks of coco-nut; both are rather difficult to ret.

It has been assumed that lignin, the substance in woody tissue, is chemically related to pectin and derived from it. Lignin does not ret at all; perhaps what is here called "hard

pectic substances" are chemically intermediates between pectin and lignin.

Cellulose.—Fibres are mainly composed of cellulose, the chemistry of which is much better known. Cellulose is a complex compound consisting of glucose units; it has no relationship to pectin. Cellulose is not affected by the retting enzyme at all; it can be decomposed by the action of certain bacteria but only under conditions which do not occur in normal retting.

However, commercial vegetable fibres like sisal are not long filaments of cellulose as artificially made rayon fibres. They have a complicated structure, consisting of ultimate fibres, which in the case of sisal have only a length of 0.8 to 7.5 mm. [3].

These ultimate fibres are bound together by small amounts of pectic substances. A prolonged retting can affect this pectic substance within the fibre, loosening the link between the ultimate fibres and weakening the commercial product.

Over-retting is, therefore, not cellulose-decomposition, but simply normal pectin-retting that has gone too far.

Retting Bacteria.—Many bacteria and micro-fungi are able to produce the pectin-disintegrating enzyme and are, therefore, used, or can be used, for retting.

The first description of a (flax-) retting bacterium was given by Van-Tieghem in 1879 and called *Bacillus amylobacter.* In 1904, Beijerinck and Van Delden published their classical treatise on flax-retting; they described two anaerobic spore-formers as responsible for anaerobic retting, *Granulobacter pectinovorum* and *G. ureocephalum* [4]. All these bacteria are nowadays considered to be variant strains of *Clostridium butyricum* [5].

Since Beijerinck's publication in 1904 a great number of retting bacteria have been discovered and described under various names. Sometimes they were used for commercial retting processes, as in the case of the Carbone-process or the Rossi-retting. The names are often confusing, various names being used in the literature for the same species. They are all spore-forming; only the most important will be mentioned here, subdivided into the following three groups:—

(1) *Obligate anaerobes.*—To this group belong the already mentioned variant strains of *Clostridium butyricum,* also *Bacillus felsineus,* discovered by Carbone in 1917 and better classified as *Clostridium felsineum.*

(2) *Facultative anaerobes.*—These are mainly *Bacillus comesii* (Rossi, 1904), *Bacillus Kramerii* (Rossi and Carbone) and *Bacillus macerans* (Schardinger), which all seem to belong to the same group, classified by Donker in 1926 as *Aerobacillus* [6].

(2) *Obligate aerobes.*—Aerobic spore-formers of the *Bacillus subtilis—B. mesentericus* group.

Besides these and other bacteria certain micro-fungi are known to ret and are probably responsible for the dew retting.

One might get the impression that retting is a rather difficult scientific process, in which pure cultures of bacteria and microscopic control play a big role. Pure cultures have indeed been tried out in flax retting, mainly to exploit some newly found bacterium commercially, but they are neither necessary nor are they producing results which could not be got otherwise.

Fortunately retting bacteria are widely spread, on the surface of the plants, in the soil, in the water; to obtain retting, some suitable conditions have only to be created. It can be difficult to find these conditions, as in fact has been the case with sisal retting but, once they are found, practical retting is a very simple process.

Sisal Retting.—As flax retting has been known for centuries, it is surprising that the application of the same principle to sisal is relatively new. The reason is probably that flax and also jute can be retted easily under various natural conditions and that sisal under exactly the same conditions does not ret at all.

(1) *Sisal Leaves.*—Retting of sisal leaves was first suggested by Carbone after the first world war. According to this investigator, sisal leaves should be immersed in water, using tanks or even barrels, and inoculated with a culture of the already mentioned *Bacillus felsineus,* discovered by him. Such a retting process was suggested as a substitute for mechanical decortication, especially for small farmers in Southern Italy. It does not seem to have been put into practice, in any case not on a bigger scale.

In 1923, the author tried at the sisal estate Djengkol in Java to ret whole sisal leaves in a similar way, using various bacteria. He came

to the conclusion that it was very difficult, not to say impossible, to get proper results.

Much better results were obtained if the fleshy matter of the leaves was crushed by rollers first. A special method of preparing line fibre was worked out, by putting the crushed leaves, or rather the bundles of fibres and adhering pulp obtained by crushing, into tanks and treating them in the same way as will be described later for flume waste. Commercially this system of line fibre winning by retting could not compete with mechanical decortication and was abandoned.

A similar process, using dry-decortication followed by retting, was recently described in this Journal by Den Doop [7] as "not a generally practicable solution", which "may work economically under limited conditions".

Rutherfoord [8] has taken out a patent on a method, according to which the leaves are crushed between corrugated rollers and then retted in "an alkaline solution of about 99 degrees Fahrenheit".

(2) *Flume Waste.*—As retting of leaves could not compete with mechanical decortication, the author experimented further with flume waste, for the reclamation of which then —in 1923—a solution had not been found.

It was first tried to ret flume waste in the same way as flax under anaerobic and facultative anaerobic conditions. But all endeavours failed, the fleshy matter of sisal refusing to ret under these conditions. A solution was at last found by retting under aerobic or semi-aerobic conditions, extracting at the same time acids, saponins, sugars and other soluble matter of sisal pulp. Two main methods for retting sisal resulted:—

(*a*) Water retting in tanks, the water flowing through the tanks in a slow but continuous stream. This streaming water serves the dual purpose of extracting the solubles and creating by its natural content of oxygen the necessary semi-aerobic conditions.

(*b*) Aerobic heap retting, piling the waste up in heaps and spraying these heaps with water.

Method (*a*) was more expensive and needed more water, but gave under Java conditions the better product. As there was plenty of water available, this method was eventually chosen for the central retting plant, erected at Laras in Sumatra in 1925-26.

Independent of this Java retting, which never was made public, were experiments with retting of flume waste made in 1937 by Beckley and Pullen Burry at Kalimoni in Kenya [9]. According to unpublished reports, anaerobic retting was also found impracticable by these investigators; an aerobic tank-retting was worked out, called saturation retting.

The principle of saturation retting is that the waste is carefully packed in tanks with a density of about 400 lb. of waste per 3 cu. ft. volume. The packed waste is covered with hessian or sisal cloth. Once in 24 hours the tanks are filled with water for a shorter or longer time according to the temperature of the waste or of the water. After retting, which lasts about six days, the retted waste is washed, either by hand or mechanically.

Difference between Flax and Sisal Retting.—Flax and jute need only be immersed for some time in water, even stagnant water, to give a more or less satisfactory retting. If the same is done with flume waste, a heavy fermentation takes place, gases are formed and the surface of the water is covered with foam. But notwithstanding this biological activity there was no or only negligible retting.

The reason for this difference in behaviour is not the different composition of the pectic substances; it is entirely due to the fact that the fleshy matter of sisal contains substantial amounts of acids, sugars, saponin and other soluble substances.

Of these solubles the acids are hampering the retting directly by bringing the pH of the water to an initial value of about 4.5, which is much too low for a rapid growth of retting bacteria. When flax is retted in stagnant water, the initial pH value is 7-8 and, therefore, neutral to slightly alkaline; it falls during retting through development of acid decomposition products to about 4 to 4.8. A low pH value is, therefore, reached in flax retting only in the last stage, when the retting work is practically done.

Sugars and glucosides are present in a rather high concentration; in a sample of undiluted sisal juice the author found in Java about 6 per cent of total sugars, expressed as glucose. They seem to have only an indirect influence on the retting, forming an excellent medium for the development of all kinds of micro-organisms and causing heavy fermentation in the tank.

Saponin is the cause of the typical foam-forming of flume water. It is not quite clear whether the saponin has a direct poisonous influence on retting or whether it is only a nuisance, making for example a retting method with blowing air into the tanks like the Rossi-retting very difficult. On the other hand, the foam-forming gives a good indication whether the solubles are sufficiently extracted; when the retting water has no longer a tendency to foam, it can be assumed that not only the saponins but also the original acids and other solubles have been removed.

Water Retting.—To make water retting for sisal a success, the soluble matter has to be extracted first by renewing the water periodically or, better still, continuously. The result is remarkable: in three to seven days, depending on the amount of water used, excellent retting takes place and after washing away the slimy remnants of retted tissue, a snow-white fibre remains.

The retting time is, therefore, not specific for this type of retting but rather a matter of water-economy. A retting cycle of seven days seems to be the most convenient; ten days can be considered as the maximum for water retting as longer retting can lead to over-retting and weakening of the fibres.

But the water is not only an extracting agent. Natural water contains a certain amount of dissolved air and by continuously renewing the water, more and more oxygen is introduced into the process. That oxygen plays an important role is shown by the fact that the retting can be favourably influenced by artificial aeration. Also the under-layers in a retting tank are retting more slowly when the water streams through the tank from top to bottom, and more quickly when it streams in the reverse direction.

It was revealed by the author in Java that in the retting tissue spore-formers of the *Bacillus subtilis* group were predominant and it is very likely that they are responsible for this type of retting. If great amounts of water are used, renewing the tank within less than an an hour, a natural pure culture of retting bacteria results as other bacteria no longer find proper living conditions.

Experiments with this Java-type of water retting were started in Kenya at the sisal estate Kalimoni in December, 1948, and no principal difference with retting under Java conditions was found. As an average, water retting in the Kenya Highlands is slower owing to the lower temperatures, especially in the cool months; but with sufficient water a seven-day cycle can also be accomplished.

As a result of these experiments it was found that for the production of one ton of dry flume tow, a seven-day water retting would require under Kenya conditions: seven retting tanks measuring 21 ft. by 21 ft. by 3 ft. deep, together with a water supply of about 400 gallons per minute.

The total depth of the tanks should be four feet. About one foot from the bottom a grate (false bottom) is made from bamboo or sisal poles. From under this grate the water is carried away by means of overflow pipes, securing a constant water level in the tank. To achieve a fair distribution of the water and at the same time a good aeration, the water should be sprayed at the surface of the tank; a cheap spraying device consists of a number of wooden channels or bamboo pipes at about two feet height above the water surface, from which the water falls down.

The tanks can be made of stone or concrete, but if the ground is sufficiently hard a much cheaper construction is possible, simply digging the tanks into the ground with sloping walls.

This type of water retting is simple and foolproof and gives a snow-white fibre of the original strength. The waste water from the tanks is fairly clean owing to the high rate of renewal and could probably be discharged into the rivers without purification; it can be used for washing of the retted material and even for the decorticator.

Notwithstanding all these advantages and notwithstanding the success of this retting method in Java and Sumatra it cannot be recommended for East Africa because of the enormous water consumption.

Circulation Retting.—In order to reduce the amount of fresh water, experiments were made with using the same water several times by pumping it back into the tanks.

As the function of the water is to extract acids and other soluble matter and to introduce oxygen, the water coming from the tanks is of course a very poor substitute for fresh water. It is no longer a supplier of oxygen but a consumer, as the dissolved organic matter uses a certain amount of oxygen for its further decomposition. This amount is measured as the "biochemical oxygen demand".

Repeated use of water leads, therefore, to high acidity in the tanks and to slowing down the retting, making the advantage of a lower water consumption illusory. The water has to be purified first, either by percolating filters or by aeration with or without activated sludge.

For flax the problem of purification and repeated use of retting water was studied in England during the war by the Water Pollution Research Laboratory and suitable methods worked out [10]. Purification of waste water from sisal by means of percolating filters was studied in Kenya by the same Laboratory and a review given by Brandon in this Journal [11].

For the experiments with circulation retting at Kalimoni, purification through a percolating filter was chosen; the aeration method and the activated sludge process need a too complicated installation to be practicable for an average sisal estate and have as an additional difficulty the very great foam-forming.

Experiments with a percolating filter of about the size of an experimental retting tank (3 ft. by 6 ft. by 3 ft. deep) showed that purification of the retting water of the first two days is not economical. This water has a high content of acids and other organic matter and would require a much bigger percolating filter than the volume of the retting tank; it would make the whole installation very expensive. It was, therefore, decided to let this water run away and to supply an equal amount of fresh water, thereby only circulating the retting water of the third and following retting days.

It is calculated that, with a system of partly circulating the water in this way, it would require per ton of dry flume tow: 280 sq. yd. of tank surface and about the same surface of percolating filters, 100 gal./min. fresh water and a circulation pump with a capacity of about 700 gal./min.

Compared with the original water retting the water consumption is, therefore, reduced to about 25 per cent, but remains still considerable. The installation is much more expensive and the method is less foolproof than the retting with fresh water. For these reasons this method also cannot be considered to be an ideal solution of the retting problem for East Africa.

Water Retting with Aeration.—Aerobic water retting by blowing air into the retting tank was introduced for flax by Rossi about 1908; the tank was inoculated with a broth culture of *Bacillus comesii* [12].

Flax retting processes with partial aeration are also known; it is assumed that in this case the retting is still achieved by anaerobic bacteria, but that the air prevents anaerobic decomposition of soluble matter and the forming of acids.

As water retting of sisal reacts favourably on aeration, it is obvious that blowing-in of air could be a method of speeding-up the process and of saving water.

Experiments with this type of retting (a modified Rossi-retting) were made with flume waste in Java in 1925, using an air-compressor and porous tiles for diffusing the air in the tanks. The principal difference between flax and sisal appeared to be the intense foam-forming in the sisal retting, owing to its saponin content. This foam is tough like whipped cream, heaving around the tanks in enormous clods and staying for days before it eventually dissolves. It makes a proper working with the installation quite impossible.

Because of this foam, aeration can only be used after the second or third day, when all the saponin is extracted, and is, therefore, only an advantage in the second stage of the retting. It could, however, still in this stage save water or make it possible to use the water several times. But it would require a rather expensive installation and would need much upkeep and supervision, owing to the danger of air-leakages, of clogging-up of diffuser units and of unequal distribution of the air.

For these reasons, aeration was not considered to be a recommendable system for small sisal estates and no fresh experiments were made at Kalimoni.

As a cheap substitute, a partial aeration was tried with a simple "aerator", made from pipe fittings, specially designed for this purpose according to the principle of the filter-pump or the jet-condenser. By means of this aerator the water was introduced from under the false bottom; it left the tank at the top through an overflow, streaming, therefore, in the reverse direction as with ordinary water retting. Through the sucking action in the aerator, a certain amount of air is introduced into the tank and bubbles through the immersed flume waste to the surface.

But even this simple form of air-introduction still causes so much foam that it can only be applied in the second stage of the retting. It influences the retting favourably, the underlayers especially being retted more quickly.

The effect is, however, not so big that it could turn the balance in favour of water retting for an estate which has not enough water.

Water Retting with Alkalis.—It is often recommended in flax retting to add some alkaline chemicals to the retting-water; as far as is known it has never been done on an industrial scale because of the high costs of the chemicals. For sisal (line fibre), retting in an alkaline solution is recommended in the earlier mentioned Rutherfoord patent [7].

As commercial success can only be expected with very cheap chemicals, experiments at Kalimoni were only made with crude Magadi soda ash. Various amounts of soda ash were added to the retting water, up to complete neutral and even slightly alkaline reaction, either in experiments with pure water retting or with circulation retting by means of the biological filter.

These experiments were a complete failure. It was neither possible to speed up the retting nor to use less water, nor could the rate of circulation be increased. If the acidity of the retting-water was reduced by adding soda ash, the water quickly regained its old level and often exceeded this level. The working of the percolating filter was even less, if soda ash was added, than without such an addition.

There is, of course, a possibility that other chemicals might be more effective (e.g. sodium and other bicarbonates) or that soda ash applied in some special way or in a certain stage of the process might give better results. The experiments were, however, not continued. It was concluded that working with neutralizing agents is not a method which could be left to Africans. Even if in further experiments a successful way would be found, it is obvious that it would require careful handling and some form of chemical control; it is not likely that the average planter would be interested in a by-product that would require more attention than the main product of line fibre.

As in the meantime other experiments had shown that a much simpler retting method was possible, further attempts of improving the water retting were given up.

Spray retting.—This new method is a special form of the spray or heap retting, tried out in Java in 1923 and since then forgotten. It is an aerobic retting without tanks. It brings the flume waste and the retting water into contact with air in a way that is simple, cheap and effective and avoids the foam-forming, which is such a nuisance with artificial aeration.

Experiments at Kalimoni proved that this type of retting works very well under Kenya conditions, but the retting is much slower than in Java. The lower temperatures in the Kenya Highlands affect spray retting more than water retting. Flume waste in heap form cools off at night more rapidly than flume waste immersed in water, as water with its high specific heat works as a temperature-equalizer. Also the fine spraying of water in the Kenya Highlands with its dry climate leads to considerable evaporation, with the result that the water is further cooled down.

This difference is also shown by the fact that in Java the surface layers of the heap, which are exposed to the direct spray, ret much quicker. They soon become slimy and can then become a nuisance, preventing the water from penetrating the heap. Under Kenya conditions, the surface layers ret even more slowly than the remainder, notwithstanding the fact that they have the best conditions of extraction and aeration. The reason can only be the lower temperature; water temperatures in Java are about 24—30° C. against 17—24° C. at Kalimoni.

A simple way of overcoming the disadvantage of lower temperature was found in spraying the water only during the day-time, instead of during 24 hours as in the Java experiments. It is known that a heap of flume waste, left to itself, becomes warmer and warmer owing to the action of thermophilic bacteria and to secondary chemical reactions of the decomposition products formed by this action. It is the same process as takes place in damp hay, straw and other organic material (mowburn); it can lead to carbonization and even to spontaneous combustion.

In flume waste, with its high water content, the reaction does not go so far; but it goes far enough to discolour, weaken and even destroy the fibres. Temperatures up to 70° C. were actually measured in such heaps; it is likely that under suitable conditions still higher temperatures can occur.

By discontinuing the spraying at night, this heat-generating process is given occasion to develop in order to compensate the effect of low water and air temperatures. The actual temperatures in a retting heap that is only sprayed during day-time vary between 30° and

38° C. according to the time of measuring and the place in the heap.

In this method of spray retting the water has a triple function: aeration, extraction and cooling. It is remarkable that quite a small amount of water compared with that used in tank retting can perform the same extracting functions. The reason is that because of the better aeration in a heap, the acids decompose much more easily than under tank-conditions. If a heap of flume waste is left to itself without adding water, it is not only developing heat but the acidity decreases within a few days and the reaction changes eventually to alkaline. However, notwithstanding this decomposition of acids, no proper retting takes pace as long as the heap is not treated with water.

The pH during various stages of spray retting shows more or less the reverse picture of anaerobic flax retting in stagnant water. In flax retting the pH decreases from 8 to 4.8 and in spray retting of sisal it increases from about 4.5 to nearly neutral and under ideal conditions of aeration even to about 8.

In practice, in a heap of 16 ft. by 16 ft. by 3½ ft. high, containing a day-production of flume waste corresponding with about one ton of dry flume tow, the conditions are never entirely uniform. Some places get more and others less water, big pieces of fleshy matter are extracted more slowly than small pieces, lower parts of the heap receive less air than higher parts and so on. Therefore the degree of retting, the temperatures and the acidity will always vary.

For example: liquid squeezed out of good retted material was found to have a pH of 6.7 to 6.8; insufficiently retted material of the same heap contained a liquid with a pH of only 5.0.

The pH of the retting water, drained at the same time from eight heaps, which represented eight days and eight different stages of retting, showed the following values:—

Retting day:	1	2	3	4	5	6	7	8
pH:	4.6	4.9	5.2	5.6	6.0	6.2	6.3	6.4

The fresh water, used for spraying, had a pH of 6.5—6.6.

It was not possible to make bacteriological investigations with spray retting at Kalimoni; it it very likely that the active retting bacteria are the same as in semi-aerobic water retting. There is, however, a remarkable difference in the flora of retting liquid of both types of retting: in water retting with a sufficiently high rate of renewal one finds practically a natural pure culture of retting bacteria; in aerobic spray retting a variety of all kinds of micro-organisms will be found. The difference can easily be seen under the microscope, comparing two samples of retting effluent of both types of retting. It means that spray retting is accompanied by all kinds of secondary fermentation processes.

This difference results in a difference of the colour of the finished product: water-retted flume tow is white, having still the original colour of sisal; spray-retted flume tow is silvery-grey. The slight discoloration by spray retting is not the effect of the retting action itself, but of simultaneous, secondary processes. This typical colour of spray-retted flume tow may be a slight disadvantage for special purposes where a very white fibre is desired, but it does not matter for most purposes and is even an advantage in manufacturing sacks.

The technical advantages of spray retting are substantial: the water consumption is only about 15 gal./min. a day for a daily production of one ton of dry flume tow (30 gal./min. during 12 hours), and the capital outlay for the retting installation is negligible. No tanks are required, not even a concrete floor, A flat piece of hard ground, if necessary hardened by a layer of stamped murram, surrounded by a low wall to mark the boundaries of the piled-up flume waste, is sufficient. The only real capital expenses for the retting installation are the sprinklers with piping, pump and water tank.

It is not necessary, and may even be undesirable, to protect the heaps by layers of hessian or other covering material. The surface of the heap, which is exposed to the sunlight, will show a light discolouring, varying from slighty brown, in months with plenty of sunshine, to a light grey in the rainy or cloudy season. The amount of fibre involved is, however, negligible and can scarcely be traced in the finished product.

Another advantage is that with this type of retting the danger of over-retting is practically nil; even after an exceptionally long spray-retting of three weeks, the fibres showed no signs of weakness due to over-retting, only some discoloration, and were still suitable for spinning.

This is a remarkable contrast to water retting, which should not be extended longer than ten days. In spray-retting the retting never goes so far, it reaches a certain point and then comes to a standstill.

This fact is not yet fully explained. It may be that, as retting progresses, as the material in the shrinking heaps gets softer and more slimy and clings more and more together, the aeration gets less and less till it is no longer sufficient, and retting consequently stops. In water retting the waste is much less compact, being lifted by the water, and aeration is less influenced by the gradually changing conditions of the material.

The fact that retting for a few days more does not weaken the fibres makes the spray retting very easy to handle. It would be possible to ret within six or seven days, but then temperatures and acidities would have to be controlled; this would mean special supervision and would make the method much more complicated. By taking the retting time at about ten days, these complications are avoided, because the longer time makes up for slight deviations from the optimum conditions.

It is not even necessary to control the retting time. In the practical form of the "boma retting", which will be described in Part III, the dimensions of the "boma" are based on an average production of ten days, and the work goes on automatically, piling up the fresh waste on one side and taking away the retted material on the other side. The actual retting time may be a little less when the production is higher and a little more when it is lower, it may be nine, ten or eleven days—it makes little difference to the finished product.

It may be mentioned here that sisal retting is never accompanied by an objectionable adour, neither in the case of semi-aerobic tank retting nor in the case of spray retting. If there is any smell at all, retting sisal has a pleasant aromatic scent like hay.

Spray retting was eventually considered to be the most suitable retting method for Kenya conditions; the first full-scale retting plant was installed at Kalimoni, using for the mechanical treatment before and after retting the machinery which had been developed in the meantime. The plant went into production in August, 1949, for a scheduled capacity of one ton of dry flume tow a day; it has worked now for more than a year without any interruption or difficulties, producing a retted flume tow with excellent spinning properties. The actual capacity was even higher than expected; up to one and a half tons of dry flume tow can be, and frequently is, produced in a shift of about ten hours.

In the third and last part, the new reclamation plant of Messrs. Sisal Products will be described; it works on the same principles as the pilot plant at Kalimoni.

Part III

The New Flume Tow Reclamation Plant

The new reclamation plant was developed by Messrs. Sisal Products for the benefit of the East African Sisal Industry as the result of the experiments described in Part II. No patent rights, licences or commissions are involved; every assistance and advice in ordering and erecting the machinery and starting the manufacture will be given. Sisal Products wants, of course, to buy the produced flume tow, but producers are under no obligation to sell and are free to export their product if they want to do so.

It is hoped that increasing reclamation of flume tow will lead to a further extension of a healthy secondary industry with the final aim of making East Africa independent of imported sacks.

Some sisal estates have already ordered the new reclamation plant and others are considering the proposition; some smaller estates, for which the capacity of the machinery is too high, are introducing retting in combination with shaking-out and washing by hand.

The standard plant is designed for a capacity of one ton of dry flume tow per working day of ten hours, corresponding to a line fibre production of about $3\frac{1}{2}$ tons or about a hundred tons of line fibre a month. The capacity of one ton of dry flume tow from the standard plant is on the safe side; it is able to deal with higher top-productions up to one and a half tons of dry flume tow a day. Working in two shifts of ten hours, the plant would be big enough for an estate producing 200 tons of line fibre a month, assuming the decortication is completed in two shifts.

In the complete plant the flume waste undergoes the following treatments:—

1. Reclamation from flume.
2. Removal of superfluous water by squeezing.
3. Separation of loose pulp.
4. Decomposition of adhering pulp by retting.
5. Squeezing out of retting water and decomposed tissues, at the same time opening up pieces of leaf, butt-ends and barky runners.

6. Further cleaning by washing.

7. Drying.

Compared with the old reclamation method, introduced by Sisal Products about 1937, the crushing of fleshy matter by rollers and the treatment in centrifugals have been omitted; the separation of loose pulp takes place in a new and more efficient machine and the retting and washing are added.

Flume Tow Balance.—The approximate quantities of material to be treated in the various stages for an original leaf-product of 100 tons are as follows:—

			tons	%
Decorticator—				
	in:	Sisal leaf	100	100
	out:	Line fibre	3·5	3·5
		Juice and pulp lost with water	63·5	63·5
		Reclaimed waste	33	33
Squeezer—				
	in:	Reclaimed waste	33	100
	out:	Water squeezed out	11	33·3
		Squeezed flume waste	22	66·7
Pulp Separator—				
	in:	Squeezed flume waste	22	100
	out:	Loose pulp	13	60
		Separated flume waste	9	40
Retting, Washing and Drying—				
	in:	Separated flume waste	9	100
	out:	Dry flume tow	1	11

The actual figures for any given estate will of course vary, depending on length and type of leaf and the working of the decorticator.

Description of Machinery

Collecting Brattice.—The waste is reclaimed from the flume by a collecting brattice, made from slats of stainless steel to avoid corrosion by acid flume water. This construction is rather expensive, but has worked in the old reclamation plant satisfactorily for more than ten years. If there is sufficient slope in the flume to place the collecting conveyor outside the acid water, a cheaper construction (wooden slats and belts) can be chosen.

Squeezer.—As an approved construction the squeezing press of Petrie and McNaught was chosen; it is therefore of the same type as in the old plant, but, of course, of the newest, improved model. The press consists of two rollers, a plain under-roller and a wool-wrapped upper roller; it applies a pressure of five tons. Of course, any squeezer of sufficient capacity and pressure will do the job, and if at an estate such a squeezer is available it can be substituted in the new reclamation plant.

Pulp Separator.—The new pulp separator, a revolving cage 12 ft. long and 3½ ft. in diameter, is a simple and effective piece of machinery, shaking out about 60 per cent of the weight of squeezed waste in the form of green pulp. It is driven from outside by gearing, making about 33 revolutions per minute, and contains no shafts or other obstacles inside. It is mounted at a slight incline; the waste is fed in by a conveyor at one side, is taken up by the revolving cage and falls down again, the loose pulp falling through the bars of the cage. This falling-down is repeated about 50 times till the waste leaves the cage at the other end, falling directly into a trolley.

The whole cage is placed at a height which allows the green pulp to fall directly into two trolleys. This pulp contains pieces of fleshy matter and cuticle and would be a good raw material for wax and pectin extraction. It can also be taken back to the land as in Java and Sumatra; it proved there to be an excellent compost, improving at the same time the structure of the soil by humus-forming.

Retting Ground.—The separated waste is brought by trolleys to the retting ground. The retting method employed is spray retting as described in Part II. This method can be used in two ways, heap and boma retting. In heap retting the product of one day is piled up round a sprinkler in the form of a circular heap, about 16 ft. in diameter and 3½ to 4 ft. high for the waste of 100 tons of leaves. Boma retting is more practical for a continuously working plant; here, instead of isolated round heaps for the daily output, one long, rectangular-shaped heap is used for the entire production of ten retting days, the fresh waste being continuously piled up at one side and the retted waste taken away at the other side.

The form of the boma can be adapted to local circumstances; it can be one long rectangle, 160 ft. long and 16 ft. broad or two adjoining rectangles each of 80 ft. by 16 ft. To mark the size of the heap, the boma is surrounded by a low stone wall, 1 ft. high at places where the waste is charged or discharged and about 3 ft. high at other places. The floor can be made of stamped murram, so sloped that all the retting water can be drained into a central drain and used again for washing purposes. On the floor is a double, cross-wise layer of sisal poles, on which the waste is piled up, three to four feet high, according to production. It is not advisable to make the heap higher than 4 ft., as otherwise the under layers would not receive enough air.

At intervals of 16 ft. from each other and 8 ft. from the sides ten sprinklers of special construction are erected.

Many experiments have been carried out to find a simple and fool-proof sprinkler construction for this special purpose. The design now in use consists of a 3 ft. long piece of half-inch pipe, into which the water is fed from the middle through a brass bush, enabling the whole pipe to turn round horizontally. At both ends of the pipe jets of $\frac{1}{4}$ in. diameter are fixed at right angles, turning the pipe automatically round by jet-action. Each jet throws the water against a little water-wheel with four wings, spinning this wheel round and dissolving the jets of water into a fine spray. There is, therefore, a double turning action, securing an even spray even should one of the jets become blocked. A sprinkler unit for a retting space of 16 ft. by 16 ft. consists of two of these arms with a total of four jets at a distance of 8 ft. from each other.

The whole construction is of the utmost simplicity, using neither ball-bearings nor parts which need oiling, and can—if necessary—be made from half-inch pipe fittings. The first (home-made) sprinklers have been working now for over a year at Kalimoni without any trouble.

The capacity of one sprinkler unit is about three gallons per minute, depending on the water pressure. A centrifugal pump with a gross-head of about a 100 feet, making about 2,700 revolutions per minute and using 5 h.p. supplies the retting water for ten sprinkler units, sufficient for one ton of dry flume tow a day.

Work with such a retting boma is of the utmost simplicity, merely consisting of the piling-up of the waste at one side and taking it away at the other side. No special controls or supervision are needed. During the night the sprinkler pump is stopped and the boma left unattended.

Washing Machine.—From the retting boma, the retted waste is transported by trolley to the washing machine.

The waste is fed by hand on a conveyor and passes first into a squeezer of similar construction to that for unretted waste. A large part of the retted fleshy matter is squeezed out here in the form of a thick, slimy, green juice ("pea-soup"); at the same time pieces of leaf, butt-ends and barky runners are opened up sufficiently, making it unnecessary to pick them out by hand.

From the squeezer the material falls directly into a long channel, where it is slowly moved forward by prongs, against a counter-current of water, being automatically lifted at the end and thrown into a trolley for transport to the drying ground.

For washing purposes, the retting water, drained from the boma, is used. If more water is available, a certain amount of fresh water can be supplied, but this is not necessary.

The waste water from the washing machine has a low acidity and, as it already contains decomposed organic matter, it is excellent for manuring purposes, particularly for vegetable gardens.

Drying ground.—After washing, the flume tow is dried by sun, no centrifugal being necessary. For drying purposes an area of 7,000 square yards is required for drying-platforms and passage-ways, per ton of dry flume tow. Retted flume tow dries more quickly than unretted tow.

Carding.—If the flume tow is sold to Sisal Products for spinning purposes, further treatment is neither necessary nor advisable, as the carding is done in the spinnery with cards specially set for the purpose. In this case the flume tow can be baled immediately after drying.

For export, the dry tow can be carded to improve its general appearance, especially if sold for purposes like upholstery, where shortening of the fibres by the action of the card is not a disadvantage.

Carding of retted tow is much easier and is superior to the carding of unretted tow. Even if pieces of fleshy matter are still left after retting, these pieces are de-gummed and their contact with the fibres is loosened. They fall out readily in the card.

The difference between retted and unretted tow can be seen when a thin layer of flume tow is spread on a piece of glass and held against the light. Impurities, which offer more resistance to the light than the fibres, appear as dark spots.

Water Requirements.—The only fresh water needed is the sprinkler water for the retting, about 30 gallons per minute during 12 hours. Compared with the water consumption of a Corona or Robey this amount is relatively small and most estates can probably spare it from the decortication—or flume water.

There are two main ways of saving water. One is the instalment of a booster pump, if the pressure of the water coming from the main pump is rather low. By letting this water pass through a second pump near the decorticator and thus giving it a high pressure, the amount of water in the drums can be reduced. In this way, at Kalimoni all the water needed for the retting has been saved, the total water consumption of the estate being the same as before.

The second way is by saving transport water. Many estates use a considerable amount of water for fluming the waste from the decorticator to the ravine or wherever the waste is disposed of. By installing the collecting brattice of the reclamation plant at a short distance from the decorticator, all this transport water can be made available for retting purposes. After retting and washing, the water can be discharged again into the flume and perform further transport functions (for example for the separated loose pulp), if required.

There are other possible ways of making the necessary retting water available, depending on local circumstances. It may be possible to store surplus water during the night in a tank for use on the retting ground in the day-time, etc. In most cases the question of water will form no insoluble problem.

Motor Requirements.—The complete reclamation plant requires about 28 h.p., subdivided as follows:—

Collecting brattice and squeezer for green waste	8 h.p.
Pulp separator	5 h.p.
Squeezer and washing machine ..	10 h.p.
Pumps	5 h.p.

Labour Requirements:—

Operation	*Number*
Supervision	1
Squeezing Press and Pulp Separator ..	1
Transport to Retting Ground	2
Building Retting Stacks	1
Transport to Washing Machine	2
Feeding Washing Machine	2
Transport to Drying Ground	2
Spreading Tow on Drying Platforms ..	2
Total	13

Characteristics of Retted Flume Tow.—The fibre recovered from spray retting is silvery-grey in colour, and is definitely of a softer texture than unretted flume tow. It contains practically no particles of fleshy matter or pulp, defects which are most pronounced in unretted flume tow, and the few runners which remain are not of a hard, barky nature but pliable and responsive to textile carding.

The dust from retted flume tow does not irritate the human skin, as the dust from unretted flume tow does; the irritation is due to minute needle-like crystals of calcium oxalate, which are extracted or destroyed during retting.

By-products.—Much attention has been given in recent years to the possibilities of recovering marketable by-products from waste pulp, as pectin or pectates, boiler detergents and wax. [1, 2, 13.]

These by-products are extracted from the fleshy matter and the cuticle of the leaf; the quality will be better and the extraction easier if the raw material is recovered as quickly as possible after decortication, having no time to deteriorate.

The pulp separator of the new reclamation plant recovers a high percentage of the fleshy matter and of the cuticle of the leaf within a few minutes after decortication and delivers it straight into a trolley. It can be considered to be an ideal instrument not only for reclaiming the tow but also for reclaiming the waste pulp for industrial (or manuring) purposes.

Another by-product is the "pea-soup" from the squeezer for retted pulp and the waste water from the washing machine, which have a high content of dispersed and dissolved organic matter in a more or less decomposed form and at the same time a low acidity. It has already been mentioned that this water has excellent properties for "aqueous manuring".

It can also be used for the production of combustible gas in Imhoff tanks [14] or other suitable digesting tanks as an additional source of power.

The author has studied gas-winning from sisal flume water by means of anaerobic fermentation in Java and succeeded in producing a combustible mixture of methane and carbon dioxide with a methane content up to 80 per cent and a calorific value up to 750 B.T.U. per cubic foot. It was found that as an average one gram of organic matter produces about one litre of gas.

Waste water from the washing machine and the squeezer will be a much better raw material for this type of fermentation than flume water, as it is much more concentrated and contains practically no acids. Gas-winning from this waste water will be easier and more economical.

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BOOK REVIEW

AGRICULTURAL SCIENCE IN THE SUDAN, By R. L. Knight and B. M. Boyns, published by T. Buncle and Co., Ltd., Arbroath, Scotland, 1950, 251 pages, Price not stated.

This book is a collection of abstracts of publications on agricultural science in relation to the Sudan, from 1838 to 1948. Long abstracts are given of the more important papers, and care has been taken in selecting those worthy of more than passing mention. The list is impressive, consisting of 969 references, arranged in alphabetical order of authors, with a comprehensive subject index. For the technical worker there is much to be said in favour of this type of reference book as compared with the more usual review volume, although it will appeal to a narrower range of readers. One important point is that the authors have called attention to earlier papers which would not normally find a place in abstract journals, and they are to be congratulated in bringing together a valuable collection of references. D.W.D.

AFRICAN FRUITS, By E. M. Baker, published by the University of London Press, 1949, 48 pages. Price 1/9d.

This book was written by a teacher of domestic science, and presents in simple language information on the appearance, food value, and use of 19 well-known tropical and subtropical fruits. It is well illustrated, and contains 28 recipes on how to prepare the fruits for the table.

CORRIGENDA

Page 43, paragraph 9, line 7 of July, 1950, edition (The Effect of Lime on a Chloris Gayana Ley, by H. P. Ledger) to read:—

> The weight in grammes per cast *multiplied by ten* gives a direct figure for the weight in pounds per acre (Freschknecht and Plummer, Agronomy Journal 41—1949).

Omit decimal points from yield in lbs./acre column in all tables.

THE VALUE OF HIDES AND SKINS

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The value of hides and skins sold overseas places these articles fourth on the list of raw materials exported from East Africa and only cotton, sisal and coffee earn greater combined incomes for the three mainland territories. The reason why this fact is not more widey appreciated is because hides and skins are by-products of animal industry with no seasonal nor geographic concentration of production. In fact, the large majority are produced individually, at irregular intervals, by the many native cattle owners scattered over the tsetse-free areas. Since they originate in such a dispersed manner, it is not surprising that the primary producer usually fails to relate the relatively small return for his individual hide or skin to the economic importance to East Africa of these same articles in bulk.

The numbers brought on to the market can be roughly divided, in decreasing sizes of output, into the productions of scattered native producers, small village butcheries, urban abattoirs centralized abattoirs and European farmers. In addition to the hides and skins purchased by traders and tanners, an unknown but, in some areas, an appreciable quantity is used by local inhabitants for such purposes as sleeping mats, clothing, ornaments, belts, paniers, water buckets, ropes and thongs, arrow quivers, shields, sword and knife scabbards, sandals, hats, cloaks, drum heads, box-like containers, stool and chair seats, aprons, etc. For such purposes, the hides and skins are used in an untanned form and it may be asked whether it would not be better for the untanned goods to be sold to traders and other or more suitable articles purchased in return. The sale of leather goods has not yet penetrated to all areas and it will be some years before these traditional uses of untanned hides and skins will be given up. So important are these domestic articles in tribal life that, during the recent war, skins were often bought by natives, for their own use, at prices in excess of those paid for overseas export.

Although hides and skins in bulk are important items in the economy of East Africa, neither the quality nor the quantity are sufficient to allow these origins to fix their overseas selling prices. Prices are fixed in relation to tannery out-turns and, in the case of hides, air-dried products are priced in relation to the values of packing-house products. Within the air-dried group, East African hides are again evaluated in comparison with other origins. In the same way sheepskin and goatskin prices are determined by the prices paid for other origins because world prices for these superior or larger supplies determine the export values of East African products and these export values, in turn, govern internal price levels.

Variations in the demand for hides and skins affect world values, and when demand falls it is the lower quality origins which are first affected. When demand increases and prices rise these lower qualities are quickly and sometimes considerably affected. Quality has placed East African hides and skins in the lower half of the world's quality list and consequently East African price levels may be erratic and sensitive to world trends. Internal prices can therefore change rapidly and this often gives rise to the erroneous impression that middlemen, dealers, and exporters are varying price offers simply for their own gain. Exporters' actions are regulated by overseas buyers and they have constantly to be on guard to anticipate changes in the world situation.

There is, therefore, no adequate answer to the often repeated question "What are my hides and skins worth?" The value is determined firstly by the level of world markets, secondly by the use to which the goods are to be put and thirdly by their quality and/or weight. Exported hides are first divided into humped and humpless categories and each category is classified into "suspension-dried" and "ground-dried". The classes are further broken down into quality grades I, II, III, IV and rejects and, within each of the quality Grades I, II, and III, the following weight ranges are separated 0—4 lb., 4—8 lb., 8—12 lb., 12—16 lb. and 16 lb. up. Selection for export therefore requires a knowledge of the trade and much of the success of an exporter depends on his ability to supply overseas buyers with the category, class, grade and weight range suitable for the production of the type of leather being manufactured by the

buyer. Anyone can collect hides and offer them for export but the best prices can be obtained only by knowledge and experience of overseas requirements.

Goatskins are classified in the same way as hides and the classes subdivided into Grades I, II, III and rejects. Offers are made overseas for these classes and qualities for certain specified weights but the problem of the exporter is, in this case, complicated by the different requirements for suede or glacé kid production. In the same way, sheepskins are classified and graded after first being separated into woolled and haired categories. In sheepskins there is more variation in substance, grain and texture between skins than in the case of goatskins and sheepskins are not only on a lower price structure because of their lower average quality, but are more sensitive to changes in world demands.

It is difficult to give figures to indicate the prices producers should receive, because not only are hides required to be sold and purchased by grade and weight and skins by grade and piece, but purchasing price is also determined by the following factors: profits, administrative and overhead expenses of all firms handling the goods between primary sale and export, physical handling and baling charges, the cost of transport to the coast, and the degree of competition for supplies. Licensed buyers are required by legislation to exhibit, at their licensed buying premises, a list of the prices being offered for each kind, class, and grade of hide or skin. A study of these price notice boards in a given area will quickly allow calculation of the losses sustained by the degrading of these articles. Hides and skins are down-graded because of brand, thorn, horn or scratch damages, sores, bruises, disease lesions, lack of cleanliness, the presence of large lumps of meat or fat, cuts, gouges or holes, hairslip, smell of putrefaction, smoke staining, insect or vermin damage, rain or water staining, poor shape, blood stains, poorly emptied blood vessels, or rubbing blemishes. Lower prices are also offered for ground dried products when compared with suspension drieds of the same quality grade.

A study of the above factors, which are responsible for down-grading, indicates that most are avoidable and that, with few exceptions, the price received depends on the care and trouble which has been taken to prevent the hides and skins being damaged during flaying, fleshing, cleaning, drying and storage. Proper attention during preparation will bring appreciable rewards as can be calculated from the prices quoted in Table I. These figures were copied from a notice board in Nairobi in December, 1950, and can refer only to the trading conditions of that particular day. They are quoted more to illustrate the differences between grades than as an indication of the prices producers can expect to receive. Between the date of these prices and the publication of this article appreciable changes in market values may have taken place.

If low prices are received for a consignment of hides or skins, the producer should not automatically blame the buyer for unscrupulous trading but should first consider in what way he has failed to take adequate care. It is more satisfactory for producers to be present when their goods are purchased because they can then learn the reasons for any down-grading and can see the appearance of good quality articles. A visit to an experienced trader will usually result in a valuable lesson regarding preparation and an improvement in the size of future cheques.

In Table II are given some statistics of production and the export value of hides and skins. The figures presented show the value of the hides and skins trade in relation to other exported raw materials. Data is also given of the 1949 exports as well as of consumptions by East African tanneries. In view of these figures, hides and skins cannot be regarded as dirty articles, unworthy of attention, the sale of which is beneath the dignity of producers. Only by encouraging the collection of all hides and skins and preparing them in the best possible manner, will it be possible to build up the industry and to enhance the overseas reputation so that high prices will be received in boom periods and a continuing demand will be ensured when markets slump.

TABLE I.—SPECIMEN PRICE QUOTATION FROM A BUYER'S NOTICE BOARD

	Humped Cattle Hides Sh. per 36 lb.		Goatskins Sh. per score		Sheepskins Sh. per score	
	Suspension Dried	Ground Dried	Suspension Dried	Ground Dried	Suspension Dried	Ground Dried
	Sh.	*Sh.*	*Sh.*	*Sh.*	*Sh.*	*Sh.*
Grade I	140	115	160	110	60	40
Grade II	130	100	130	100	50	30
Grade III	115	85	105	90	40	20
Grade IV	45	35	10	10	10	10

TABLE II A

THE VALUES OF THE CHIEF ARTICLES OF EXPORT, 1949

	Kenya	Uganda	Tanganyika	East Africa
	£	£	£	£
Cotton	248,374	17,342,765	2,059,779	19,650,918
Sisal fibre, tow and flume tow	2,851,823	68,124	11,111,232	14,031,179
Coffee, roasted and unroasted	1,516,345	2,891,006	1,460,853	5,868,204
Hides, skins and leather	1,181,003	491,460	626,419	2,298,982
Oilseeds	105,454	1,317,211	505,492	1,928,157
Wattle bark and extract	999,998	2,496	104,218	1,106,712
Diamonds	2,245	—	1,010,345	1,012,680
Tea	716,641	223,087	69,708	1,009,436
Gold	279,277	6,521	619,941	905,739
Pyrethrum	604,620	—	26,100	630,720

TABLE II B

1949 VALUES OF HIDES AND SKINS INDUSTRY

	Exported		Used by local Tanneries		Total	
	cwt.	£	cwt.	£	cwt.	£
Ground dried hides ..	42,839	248,906	11,630	69,880	154,562	1,202,588
Suspension dried hides ..	100,093	883,802				
Ground dried sheepskins ..	4,277	27,569	3,140	28,260	19,633	176,540
Suspension dried sheepskins	12,216	120,711				
Ground dried goatskins ..	10,128	150,061	626	16,276	38,736	988,201
Suspension dried goatskins	27,982	821,864				
Other skins	2,712	40,025	185	2,775	2,897	42,800
Total .. .. £		2,292,938		117,191		2,410,129

THE ROOT SYSTEMS OF SOME BRITISH SOMALILAND PLANTS—II

By P. E. Glover

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(A) GRASSES

Andropogon cyrtocladus Stapf, vernacular "Dur" (Diagram 7).

Vegetation type: *Acacia bussei*, open woodland and plateau grass.

Locality: Plateau, Jerin; edge of Arorih Plain. Latitude 9° 30′ N. (approx.), longitude 45° 21′ 30″ E. (approx.); altitude 3,860 feet.

Annual rainfall: Between 4″ and 6″ (Hunt, 1945).

Andropogon cyrtocladus Stapf is a tall, coarse grass which occurs frequently on the Plateau and abundantly in the Haud. It has an altitude range of 1,500 ft. to 4,000 ft. Under optimal conditions of soil and rainfall, it will grow to 12 ft. high and form solid clumps 10 ft. or more in diameter. The specimen discussed here, was examined at Jerin, where it formed part of a small "island" associated with *Acacia bussei* Harms, *Acacia arabica* Willd. and *Acacia spirocarpa* Hochst.

This plant formed a tussock 75 cm. high and 65 cm. wide. It had an overall lateral root development of 2.3 metres and its roots were traced to a depth of 1.2 metres, but it was not possible to trace them further as they penetrated a hard layer of travertine.

The stem bases from which the roots emerged were swollen and bulbous and sometimes up to 2 cm. in diameter. The main roots were tough and fibrous, arose from the stem bases at right angles to them, and had an outer creamy, crinkly sheath.

In the first 20 cm. of soil there were numerous short rootlets coming from the main roots.

From 20 cm. to 40 cm., several of the roots were dead. The first 50 cm. of soil was a fine grey clayey loam and in this layer the greatest root activity occurred. At a depth of 50 cm. numerous calcareous concretions appeared in the soil and their presence caused much twisting and crinkling in the main roots as they threaded their way between them. Sometimes several roots grew together through one sheath.

At a depth of 75 cm. the calcareous concretions become almost solid and it was very difficult to trace the roots. At 1 metre these calcareous concretions had formed a hard solid mass penetrated by many holes and fissures into which a few of the main roots continued to grow downwards, but it was impossible to trace them further although small pockets of soil still occurred in the holes into which they had penetrated.

Just after the first rains *Andropogon cyrtocladus* begins its growth by sending out short crinkly, succulent shoots which are much relished by stock. After periods of drought when the larger tussocks have become dry and tough the Somalis sometimes burn them down to induce a flush of fresh shoots, but these burns are often hot, kill off other vegetation including trees and burn the grass tussocks themselves down to ground level. In most cases a flush of green shoots appears shortly after the burn, but the plants seldom recover from the undue pressure placed on their root reserves by such drastic treatment and die off completely before the next growing season. In this way large areas have been laid bare in the past, especially in the Haud and the *Andropogon* may never reappear or take many years to do so.

The mature stems which are very tough and pliant and are sometimes up to 2 metres in length and 5 or 6 mm. in diameter, are extensively used by the Somalis for constructing their "gurghis", or native huts.

As a check on the plant examined at Jerin, the root system of a plant of *A. cyrtocladus* was studied at Alablah in the Haud. The tussock was 50 cm. high, and 40 cm. in diameter. The lateral roots had an overall extent of 1.25 metres and the vertical roots were traced to a depth of 85 cm. where several of them passed into cracks in hard, white, shaley limestone. Apart from this, the general trend and texture of the roots were the same as those of the plant examined at Jerin, but in this case the soil in which the plant grew was the same as that described for *Aristida papposa* Trin. and Rupr. (*see* later). The roots were creamy white and most of them had a "puffy" looking dead mycelial casing around them.

Aristida kelleri Hack., vernacular "Birhe" (Diagram 8).

Vegetation type: *Commiphora, Acacia,* tree, shrub and grass.

Locality: Haud, Alablah Balleh. Latitude 8° 1′ N. (approx.), longitude 45° 1′ E. (approx.); altitude 2,500 feet.

Annual rainfall: Between 6″ and 8″ (Hunt, 1945).

Aristida kelleri Hack. is a common plant in the Haud, on road sides, cattle paths, trampled and overgrazed places and on areas laid bare by fire. It forms a small, flattish, wiry tussock up to about 30 cm. in height.

The overall extent of the lateral roots of the plant examined was 1.6 metres and they penetrated the soil to a vertical depth of 90 cm. The main roots were yellow-cream in colour and fibrous with clusters of fine rootlets coming off them at right angles.

The plant was an old one and most of the main roots were dead along a large part of their length. The greater number of roots went down almost vertically, but there was some lateral development in the first 15 cm. of soil.

There was a low mound of soil at the base of the tussock which was composed of a yellow-red, medium fine-grained sand. Beneath this for the next 15 cm. was a slightly darker layer fairly rich in organic matter. From there down to a depth of 55 cm. the soil was a dark red, homogeneously fine grained, more compact sand. From 55 cm. to 80 cm. the soil was dark red and homogeneously fine grained, but contained pebbles of varying sizes. At 80 cm. a layer of hard white decomposing shaley limestone was struck.

When the plant is young and green it is grazed by stock, but when it is old and dry it is wiry and unpalatable.

Aristida papposa Trin. and Rupr., vernacular "Machen" (Diagram 9).

Vegetation type: *Commiphora,* Acacia, tree, shrub and grass.

Locality: Haud, Alablah Balleh. Latitude 8° 2′ N. (approx.), longitude 45° 1′ E. (approx.); altitude 2,500 feet.

Annual rainfall: Between 6″ and 8″ (Hunt, 1945).

Aristida papposa Trin. and Rupr. like *A. kelleri* Hack., is a colonizer of road sides, paths and overgrazed, trampled and burnt areas in the Haud. Its tussock is not as flat as that of *A. kelleri* Hack, and it may grow to a height of 45 cm. This specimen was growing about 20 metres to the left of the *A. kelleri* discussed above. Its root system was similar, in that the roots had the same texture and were creamy-white in colour, but the main roots grew downwards to form a more or less uniform fan which was not so clearly marked in the roots of *A. kelleri.*

The root system had an overall lateral development of 1.5 metres, and penetrated vertically into the soil to a depth of 70 cm. The main roots had clusters of short rootlets coming from them at right angles. The soil was the same as that described above.

Aristida papposa is grazed by all types of stock when young and green, but becomes very wiry and unpalatable when old and dry. The Somalis use the fine stems and leaves for making mats.

Chrysopogon aucheri var quinqueplumis Stapf, vernacular "Daremo" (Diagram 10).

Vegetation type: *Acacia bussei.* Open woodland and plateau grass.

Locality: Plateau; Jerin; edge of the Arorih Plain. Latitude 9° 30′ N. (approx.), longitude 45° 21′ 30″ E. (approx.).

Annual rainfall: Between 4″ and 6″ (Hunt, 1945).

Chrysopogon aucheri var quinqueplumis Stapf has a very wide altitude range (i.e. from 1,500 to 7,000 feet). It is one of the most widely spread grasses in the country and occurs in all the vegetation types mentioned in this paper except *Balanites and Maerua Coastal Shrub,* etc. It may grow to a height of 60 or 70 cm., but seldom grows higher than 15 to 25 cm. as it is closely cropped by stock.

This plant was examined at Jerin about 100 metres south of the *Andropogon cyrtocladus* Stapf specimen (described above). It was very closely cropped and its roots were exposed for about 5 cm. above the ground. There was an overall lateral development of 1.5 metres and the vertical roots were traced to a depth of 1.2 metres. There were a few thin intertwined mycelial strands around the outsides of the main roots.

The soil was a very fine grey clayey sand to a depth of 50 cm. In the first 20 cm. there were numerous air spaces up to 2 mm. in diameter. At 50 cm. nodules of travertine appeared and the soil seemed lighter in colour. From 60 cm. to 80 cm. travertine became increasingly abundant, and at 90 cm. it became a solid layer. Several main roots continued downwards

through the crevices in it and it was not possible to trace them further.

The root system of a tussock of *Chrysopogon* was examined at Alablah in the Haud to see whether different conditions of soil and climate exerted any influence on its general morphology, when compared with the one examined at Jerin.

The plant at Alablah was 30 cm. high, 22 cm. wide and ungrazed. The overall lateral extent of the roots was 1.2 metres and the vertical roots continued to a depth of 85 cm., where a layer of hard, shaley limestone appeared. Several of the large roots grew down into the limestone.

On the whole the plant at Alablah had a greater number of roots emerging from the base of its tussock, the side branches were more robust than those at Jerin and there was a profusion of fine fibrous rootlets down to a depth of 38 cm. which were yellow-fawn in colour, and the secondary rootlets did not branch off so markedly at right angles to the main roots as they did at Jerin. Apart from these differences the general shape of this root system was the same as the one examined at Jerin.

The soil in which the Alablah plant grew was exactly the same as that described for *Aristida Kelleri* Hack. (above).

Chrysopogon aucheri var quinqueplumis Stapf is one of the best grazing grasses in the country. In the Haud it is often found in association with *Andropogon cyrtocladus* Stapf and *Indigofera sparteola* Chiov., but it is essentially a plant of the plains and is not frequent in the denser *Commiphora* thickets. In the *Acacia bussei open woodland and plateau grass community* it occurs very extensively, sometimes in association with *Sporobolus marginatus* Hochst. It is often the main constituent of the grass cover on the wide plains of the Central Plateau.

On the plains in the Haud where there has been no good rain for several seasons, tussocks of dry, rank *Chrysopogon* are frequent and in this state it is not eaten readily by stock, but they will graze it in time of extremity. The Somalis in the Haud often burn it when it becomes dry and rank, but like *Andropogon cyrtocladus* Stapf, burning usually kills it off after the first flush of growth.

Eragrostis hararensis Chiov., vernacular "Guban-Gub" (Diagram 12).

Vegetation type: *Balanites* and *Maerua* Coastal Shrub, *Acacia*, grass and desert scrub, with *Tamarix* Tug Vegetation.

Locality: Guban, Zeilah Plain, two miles NE. of Silil. Latitude 10° 59′ N. (approx.), longitude 43° 22′ E. (approx.).

Annual rainfall: Between 4″ and 6″ (Hunt, 1945).

The plant examined was 3 cm. high and 7.5 cm. wide. It had a different root system from most of the grasses studied thus far for its maximum development was in the vertical plane (i.e. its overall lateral development was only 20 cm. as against a vertical penetration of 60 cm.).

The top soil was wind-blown sand for a depth of one centimetre but for the rest it was the same as the soil described for *Panicum turgidum* Forsk (*see* below).

The first 25 cm. of soil consisted of a medium fine-grained loose sand. This became coarser down to 25 cm., after that it became hard and tightly packed.

The roots themselves were very much like those of *Panicum turgidum* and had similar swellings towards their tips. Many of them did not have active growing tips, but ended abruptly in "dry" tips. On the whole the fine secondary rootlets were finer, longer and more filamentous than those of *Panicum turgidum.*

Eragrostis hararensis Chiov. is a very frequent plant on the sandy alluvial soil of the Guban, from sea level to about 2,500 ft. It may form a tussock up to 30 cm. high and of about the same width, but generally it forms a straggly, prickly tussock 10 to 15 cm. high and about 10 cm. wide.

The awl-shaped leaves are hard, prickly and up to about 2 cm. long and 3 to 5 mm. wide at the base. The white, half-mooned shaped, fringed ligule is clearly marked. The nodes are short, and the root stocks are often bulbous and irregularly nodular.

The plant is grazed by stock when it is green and fresh. In wind-scoured areas or areas which have been heavily trampled, the roots may be exposed several centimetres above the ground, whereas in other places the plant may be almost entirely covered by wind-blown sand.

Panicum turgidum Forsk., vernacular "Dungara" (Diagram 13).

Vegetation type: As for *Eragrostis hararensis* Chiov.

Locality: As for *Eragrostis hararensis.*

Annual rainfall: As for *Eragrostis hararensis.*

Panicum turgidum Forsk. is a very common plant in the Guban from sea level to about 2,500 ft. It is also an important colonizer of wind-blown sand dunes, and because it has an extensive interlaced root system it is a very good soil binder. It forms loose, wiry, straggly tussocks sometimes up to 1 metre in diameter and one metre high or more. The stem bases and root stocks are bulbous and irregularly nodular.

The plant discussed here formed a small, loose, closely cropped tussock 25 cm. in diameter and of the same height. The overall lateral development of its roots was 3.42 metres and the main vertical roots penetrated the soil to a depth of 1.16 metres. One of them might have continued deeper if it had not curved out into the wall of the bisect pit and been cut off. The main roots emerged straight from the stem bases and for the first 25 cm. of their length they formed a loosely woven mass with many fresh growing points.

For a few centimetres from the surface downwards, the old main roots were hard and fibrous, but the small young roots were white and fleshy and covered with a profusion of short lateral rootlets. There was a certain amount of lateral root development down to 70 cm.

The soil was composed of four layers. The top layer was a medium fine loosely packed alluvial sand, the next was a loosely packed fine alluvial sand the third and thickest layer was composed of a coarser fairly loosely packed sand. The fourth was a very tightly packed sand.

Immediately beneath this was a layer of black very fine-grained clayey soil rich in organic matter but only about 5 cm. thick. In this layer there was a great deal of activity. Beneath this, was a thin layer of very fine soft sand. Then came a layer of dark brown, damp, fine-grained, clayey soil 20 cm. wide. This layer and the one above it marked the zone of greatest root activity. Next followed a layer 20 cm. wide of medium fine sand containing some organic matter partly decayed. Beneath this came a layer of very moist closely packed fine sand. The next was a wide layer of fine sand containing a profusion of partly decomposed leaf mould and other organic matter. There was some lateral root development in this layer also. The growing tips of the roots were swollen and covered in stout root hairs.

The roots of three tussocks were examined and all showed the following characteristics: there was much branching, especially wherever a clayey layer appeared, the roots swelled out towards the tips and became soft and succulent; root hairs were numerous at the root tips and sand particles adhered to the outer covering of the roots.

The soil was visibly moist from a depth of 5 cm. below the surface downwards and became moister in the clayey layers. Even though this sandy soil was soft and loose when moist, it set hard when dry.

Sporobolus marginatus Hochst., vernacular "Dihi" (Diagram 14).

Vegetation type: *Acacia bussei,* open woodland plateau grass.

Locality: Central Plateau, Jerin. Latitude 90° 30′ N. (approx.), longitude 45° 21′ 30″ E. (approx.); altitude 3,860 feet.

Annual rainfall: Between 4″ and 6″ (Hunt, 1945).

Sporobolus marginatus Hochst. is a widely spread plant on the plateau and is found most frequently on the plains at altitudes ranging from 2,500 ft. upwards. It is very frequent on the Arorih Plain and forms a wide, flat, very close tussock seldom more than 5 to 10 cm. high.

The plant examined had an overall lateral root development of 1.2 metres, and its vertical roots penetrated into the soil to a depth of 50 cm. The main roots were thin and fibrous with numbers of short lateral rootlets coming off at right angles.

The soil was almost identical with that found in the *Chrysopogon* pit (which was about 20 yards to the right of it), except that in this pit solid travertine was struck at 50 cm. but none of the main roots penetrated more than 1 cm. into it.

This soil was a fine, grey, clayey sand with some dark organic matter in the first 15 cm. and with numerous air spaces in it from the surface down to 20 cm. From there it became progressively lighter in colour until the white travertine layer was reached.

Sporobolus marginatus Hochst. is a good grazing grass and because of its low close "mat" formation, is very resistant to trampling. On the Arorih Plain it traps a certain amount of wind-blown sand thus acting as a soil "binder".

CONCLUSIONS

From the above descriptions and diagrams the following conclusions may be drawn:—

(1) All the grass root systems from the Plateau and the Haud are more or less fan-shaped and seldom penetrate the soil deeper than 1 metre, because travertine, limestone or a hard soil layer appears at about that depth. (This may account for the fact that grasses such as *Andropogon* and *Chrysopogon* are not fire resistant.)

(2) *Eragrostis hararensis* Chiov. appears to have a greater vertical than lateral root development habit and like *Panicum turgidum* Forsk. sometimes has bulbous swellings towards the root tips.

(3) *Panicum turgidum* Forsk. has a deep root system as well being well developed laterally, probably because it grows in deep alluvial and wind-blown soils. It appears to be resistant to overgrazing and trampling.

(4) The general form of the root systems of *Andropogon cyrtocladus* Stapf and *Chrysopogon aucheri* Stapf, are more or less the same in regions as widely apart as Jerin and Alablah.

(5) *Aristida kelleri* Hack. and *A. papposa* Trin. and Rupr. have the usual fan-shaped root systems.

(6) In the deep alluvial sandy soils of the Guban, wherever a layer of heavier or more clayey soil appeared the plants examined showed an intensified development of secondary lateral roots and rootlets. These layers were almost always visibly moister than the looser, coarser layers.

(B) FORBS

(*Herbs other than grasses.*)

All the following forbs were studied within a few feet of one another, in the same locality and under the same soil conditions as those of *Panicum turgidum* Forsk. and *Eragrostis hararensis* Chiov. (*See* A—Grasses above.)

Vegetation type: *Balanites* and *Maerua* Coastal Shrub, *Acacia*, grass and desert scrub, with *Tamarix* Tug Vegetation.

Locality: Guban, Zeilah Plain, two miles NE. of Silil. Latitude 10° 50′ N. (approx.), longitude 43° 22′ E. (approx.); altitude 200 feet (approx.)

Annual rainfall: Between 4″ and 6″ (Hunt, 1945).

Aerva tomentosa Forsk., vernacular "Sorna" (Diagram 14A), is a common forb in disturbed areas in every part of the country from sea level to 7,000 ft. or more.

The plant studied at Silil was 15 cm. high with a stem of 0.5 cm. thick at ground level. The overall extent of its lateral roots was 3.6 metres. Vertically they penetrated the soil to a depth of 1.4 metres. There was a strong tap root from which branched five long lateral roots which continued straight out horizontally. The longest of these was 2.3 metres.

Great numbers of short filamentous rootlets branched off at right angles to the main roots and were often encased in a sheath of fine soil particles. Some of the large main roots were black on the outside for a large part of their length, but the growing tips and the younger roots and rootlets were white.

The soil was composed of layers of alluvial sand of different thicknesses which varied from coarse fairly loosely packed sand to heavy, clayey, black soil rich in organic matter. (cf. *Panicum turgidum* Forsk.)

As its name suggests, *Aerva tomentosa* Forsk. has "woolly" leaves and is not a very good fodder plant, but is grazed by sheep and goats.

Anticharis linearis Hochst., vernacular "Indatire" (Diagram 15).

This plant is fairly common in the Guban up to about 2,500 ft. It is a small annual forb averaging 15 cm. in height. The specimen examined here was growing a few metres away from the *Aerva tomentosa* Forsk. It was about 10 cm. high and its stem was 3 mm. thick at soil level. It was growing in soft sand which had filled a narrow crack in a tug wall. Its overall lateral root development was 1.45 metres and its vertical roots penetrated the soil to a depth of 50 cm. Its taproot branched profusely about 7 cm. below the surface into strong laterals which grew out horizontally. There were fairly thick, profuse, secondary rootlets many of which had a sheath of fine

sand grains around them. From 10 cm. downwards the soil was sandy mud.

At a depth of 30 to 40 cm. the average number of roots per square centimetre of soil was two.

The local Somalis, of the Esa tribe, say that if sheep or goats graze this plant they become temporarily blind.

Citrullus vulgaris Schrad., vernacular "Unun" (Diagram 16).

This is a common prostrate creeper on roadsides, the sites of old "kharias" and other disturbed places. The aerial parts of the plant examined at Silil had an overall horizontal extent of about 1 metre, whereas the overall lateral root development was 3.45 metres and its roots penetrated vertically into the soil to a depth of 90 cm.

Two large lateral roots branched off horizontally from the tap root in the first 10 cm. At first the tap root curved about, then it continued downwards inclining steeply to the right. At 45 cm. and 47 cm. lateral roots went off horizontally again. From 50 cm. downwards secondary rootlets became profuse. The roots were whitish in colour and rather fleshy on the outside, but tough and fibrous inside.

The soil was sandy alluvium built up of layers of varying thickness and textures down to a depth of 50 cm., when several layers of heavier more clayey soil rich in organic matter were reached. Numbers of secondary rootlets were produced in these layers.

The leaves of *Citrullus vulgaris* Schard. are grazed by stock and the fruits which are like small water melons (sometimes up to 15 cm. in diameter) are fed to stock in the dry season.

Indigofera ruspoli Bak. f. Vernacular "Jelab" (Diagram 17).

Vegetation Type: Haud Sub-type, *Acacia*, Tree and Shrub.

Locality: Guban, Ged Dobo. Latitude 10° 7′ 30″ N. (Approx.); Longitude 45° 12′ 30″ E. (Approx.); Altitude 1,900 feet.

Annual Rainfall: Between 8″ and 10″ (Hunt, 1945).

Indigofera ruspoli Bak. f. is very widely spread throughout the country and has an altitude range of 100-4,500 feet. It is particularly abundant in the Haud and the Guban. In the Guban it seems to have a preference for alluvial soil. The plant examined at Ged Dobo was 20 cm. high and 40 cm. wide. It was made up of a cluster of closely packed stems, some still adhering to one another longitudinally, but others were free and appeared to have broken away by longitudinal fission. The stems were covered in a dark, grey, loose, stringy bark which sloughed off in threads.

There was a small wind-blown sand mound 5 cm. high at the base of the plant. The overall lateral development of the root system was 1.9 metres, and the vertical roots penetrated to a depth of 1.6 metres. Several lateral roots grew out horizontally into the small sand mound, and sent out secondary rootlets to within 2 or 3 mm. of the soil surface. Each large main root emerged from the base of the bunched stems and had its counterpart in a complete stem or a branch that had not yet broken away. There was a zone of great root development in the first 20 cm. down from the surface, where there was a profusion of lateral branches and secondary rootlets. The tips of many of the main roots were dead. In one instance, at a depth of 20 cm., a main root passed right through a dead root sheath of some other plant, which was about 20 cm. long and 2 cm. thick.

The first 5 cm. of soil was loose fine sand. Then there was 15 cm. of sandy alluvial grey soil with some dead root material and other organic matter in it. The next 10 cm. was a heavier more compact soil. This layer appeared to have acted as a moisture and root barrier, for most of the root activity was above it. The next 10 cm. consisted of a loose gravel, which gave place to 20 cm. of coarse but heavier grey soil. This passed into a coarse, harder, more tightly compacted gravelly soil with occasional large stones in it. This in turn passed into a layer more than 80 cm. wide of very hard, tightly compacted, coarse, gravelly, grey soil with occasional large pebbles and stones in it.

The day before the pit was dug, 1 inch of rain fell over a period of about one hour. When the pit was dug the visible moisture penetration line into the soil was 30 cm. and down to as far as the top of the coarse, loose, gravel layer.

The main roots were fairly tough, fibrous, dirty white grey in colour and had numerous filamentous secondary rootlets emerging from them. These had numbers of small bacterial nodules on them. Examination with a hand lens showed that the nodules were made up of twisted clusters of enlarged root hairs.

The young shoots when examined were found to be covered with fairly stout hairs and the leaves were covered with closely packed symmetrically arranged rows of short stiff hairs.

Indigofera ruspoli Bak. f. is very extensively grazed by stock and probably has a high nutritive value. When the shoots are young and fresh they are very much relished by stock, but in the dry dormant season the short fibrous branches become very hard and tough and thus protect the plant to some extent. This plant seems to be very resistant to grazing, trampling and exposure. Sometimes it may be almost completely covered over with wind-blown sand, whereas on other occasions its roots may be exposed for 10 or 15 cm. above ground.

Gillett (1941) in discussing the plants of the Guban sub-desert type writes: "The diverse effect of wind erosion on the grasses and the *Indigoferæ* in this community are worth mentioning. The grasses rarely have the soil blown away beneath them, as their numerous fibrous surface roots bind it, and they form low hillocks. The taproots of the *Indigoferæ* afford no such protection and nothing is more common than to see a length of 10, 20 or 30 cm. exposed by the wind. A certain amount of exposure, however, does not seem to do much damage to the *Indigoferæ*, while it kills the grasses".

Where the *Indigoferæ* are concerned he is right, but where grasses are concerned, it has been demonstrated in this paper that *Eragrostis hararensis* Chiov. does not seem to have a good lateral development and has often been observed with several centimetres of its roots exposed. It does not appear to be a good soil binder. *Panicum turgidum* Forsk. is a good soil binder, but does not appear to suffer any serious effects from a few centimetres of root exposure, as its root system is deep and robust and it need not draw its reserves from the first few centimetres of soil.

Indigofera spinosa Forsk. Vernacular "Machin" (Diagram 18).

Vegetation Type: Haud Sub-type, *Acacia*, Tree and Shrub.

Locality: Guban, Ged Dobo. Latitude 10° 7′ 30″ N. (Approx.); Longitude 45° 12′ 30″ E. (Approx.); Altitude 1,900 feet.

Annual Rainfall: Between 6″ and 8″ (Hunt, 1945).

Indigofera spinosa Forsk. is another plant which occurs in most parts of the country. It grows to a height of 20 cm. or 30 cm. and about the same width. It is very similar in appearance to *Indigofera ruspoli* Bak. f., except that it is covered with spines sometimes 1 cm. or more long, which cause urtication when touched.

The young shoots have a number of stout straight hairs on them and the leaflets are covered with closely packed rows of stiff short hairs.

The leaflets (usually 3 to each leaf) have a decided fold down the midrib and some of them have a short mucronate tip, while others appear to be more or less emarginate.

The plant discussed in this paper was 5 cm. high and 6.5 cm. wide. It was examined in the same pit as *Adenium somalense* (*see* under Succulents, Part I). Its overall lateral development was 50 cm. and its vertical main root penetrated to a depth of 55 cm. From there it had continued downwards, but was impossible to trace further as it had died off and disintegrated. This root system was very similar to that of *Indigofera ruspoli* Forsk. except that there was only one vertical main root with several large lateral roots coming off it.

The plant was made up of only one main stem and not an aggregate, as was the case with *I. ruspoli* Forsk. The larger roots were dirty creamy grey in colour with numerous fine secondary rootlets attached to them. These too had many small bacterial nodules on them. When examined with a hand lens the nodules were seen to be composed of loose bunches of long stout enlarged root hairs.

In the first 10 cm. the soil was a fine, loose, micaceous sand with some organic matter in it. From there downwards it was composed of a coarser grey micaceous sand.

A day after half an inch of rain had fallen, it was found that moisture had penetrated 35 cm. into the soil.

The fresh green shoots of *Indigofera spinosa* are grazed by sheep and goats. But in the dry season the toughness and spininess of the plant makes it unpalatable. It probably has a high feed value. It appears to be resistant to grazing and trampling and does not seem to be any the worse for being almost buried in sand, or having the upper parts of its main root exposed.

(All the plants described below were studied at Silil in the Guban in the same area as *Aerva tomentosa* Forsk.)

Oldenlandia Sp. Vernacular "Manjaaso" (Diagram 19).

This plant is common in the Guban in sandy alluvial soil. It is a slender, straggly annual which may reach a height of 30 cm.

The specimen examined was about 20 cm. high and its stem was 3 mm. thick at ground level. It had an overall lateral root development of 65 cm. and its main root penetrated vertically into the soil to a depth of 70 cm. The lateral roots branched off more or less horizontally from a fairly stout taproot. The roots were white in colour, soft on the outside but fibrous inside. Some of the roots on the left-hand side of the plant had purplish brown marks on them while between 30 or 40 cm. down, the main roots had numerous minute hairs on them.

The soil was a medium fine alluvial sand from the surface to a depth of 20 cm. From there to 30 cm. it was a very fine moist alluvial sand. From 30-40 cm. it was a coarse, moist alluvial sand and from 40 cm. downwards, it was a very fine soft sand.

Oldenlandia sp. is grazed by stock.

Mallugo sp. Vernacular "Karo" (Diagram 20).

This is a small very delicate annual forb up to 10 cm. high, sometimes frequent on sandy alluvial soil in tugs in the Guban.

The plant examined was about 5 cm. high and 10 cm. wide. Its stem was 1 mm. thick at soil level. It had an overall lateral development of 45 cm. and a vertical development of 95 cm.

The long slender taproot went almost straight down while the delicate filamentous lateral roots continued out sideways for a portion of their length then turned downwards again. There were frequent, secondary, filamentous rootlets which at a depth of 45 cm. occurred to the average extent of 5 per square centimetre of soil. The soil was a fine sandy alluvium, which became moist at a depth of 20 cm.

Mollugo sp. is so small and delicate that it is of no value for grazing, although numerically it can be an "ephemeral" dominant.

Sida sp. Vernacular "Mirageljire" (Diagram 21).

Sida sp. is a small perennial forb with a single main stem which may reach a height of 60 cm.

The plant studied at Silil was 5 cm. high and its stem was 3 mm. thick at ground level. It had an overall lateral root development of 50 cm. and a vertical root development of 1.35 metres. There was a fairly sturdy taproot which gave off smaller lateral branches down to 70 cm., when it split up into two bundles of 5 and 8 roots, each enclosed in a sheath. At 8 cm. the fine roots emerged from the sheaths and gave off numbers of secondary filamentous rootlets. All except one root from each bundle disappeared at 1.1 metres.

The soil was a fairly fine-grained alluvium throughout. From 30 cm. to 47 cm. downwards it was soft and loose when damp, but hard and coarse when dry.

The root systems of two other plants 5 cm. and 7.5 cm. high respectively were examined. In the plant 7.5 cm. high the taproot branched into two, 10 cm. below the surface. One branch went out sideways and the other continued straight down to a depth of 51 cm., then it turned off horizontally and went into the wall. The plant 5 cm. high had a stem 3 mm. thick at the soil surface. Its taproot went straight down for 61 cm. Secondary lateral rootlets were numerous near its tip. Two very fine lateral roots branched off the taproot 7.5 cm. from the surface and continued sideways, one for 8 cm. and the other for 5 cm. The soil was the same as that described for the first plant.

Sida sp. is grazed by sheep and goats.

Tephrosia sp. Vernacular "Farader", "Tima der" or "Lebi-Vero" (Diagram 22).

Tephrosia sp. is a fairly common, semi-prostrate perennial forb in the Guban. It is usually found on sandy alluvial soil and may reach a height of 15 cm.

Two small plants were examined at Silil. One was 3 cm. high with part of its taproot exposed. The taproot was 3 mm. thick at the soil surface. The overall lateral extent of the roots was 85 cm. and their vertical extent was 1.23 metres.

The taproot did not continue down in a straight line but twisted to the left at a depth of 10 cm. From 20 cm., it twisted back to the right and then went more or less straight downwards. At 40 cm. a large lateral root branched off to the right and at 70 cm., other smaller laterals branched off. The roots were

white in colour, tough and fibrous, with numerous secondary filamentous rootlets. No bacterial nodules were seen.

As a check on the first, another plant was studied. This had a stem 3 mm. thick at the soil surface to which a few leaves were attached.

Its taproot continued straight downwards to a depth of 90 cm. One lateral root 33 cm. long, branched off and continued in a horizontal direction. Other short laterals branched off at varying points along its length. At a depth of 80 cm. a profusion of short filamentous lateral and secondary rootlets appeared. The roots of this plant had the same general appearance as the one previously described. No bacterial nodules were seen and the soil was the same as that described previously.

Conclusions

From the above diagrams and description the following conclusions may be drawn:—

(1) In the sandy alluvial soil of the Guban the root development of forbs is extensive in relation to the size of the aerial parts.

(2) *Anticharis linearis* Hochst. although it is only a small annual forb had an extensively developed lateral root system.

(3) In the case of *Indigofera ruspoli* Bak. f. a layer of heavy clayey soil appearing at a depth of 20 cm. seemed to act as a barrier which promoted lateral root development and retarded vertical penetration.

(4) Bacterial nodules made up of bunches of enlarged root hairs were frequent on the secondary rootlets of *Indigofera ruspoli* Bak. f. and *Indigofera spinosa* Forsk. but were not seen on *Tephrosia sp.* at Silil.

(5) The clear distinctive colours of the roots in the Silil area contrast with the dull indistinct grey and brown or roots in other parts of the country.

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DIAGRAM 7

ROOT BISECT OF ANDROPOGON CYRTOCLADUS STAPF. "DUR"

JERIN-ON AROBIH PLAIN, BURAO DISTRICT, 16TH AUGUST 1945

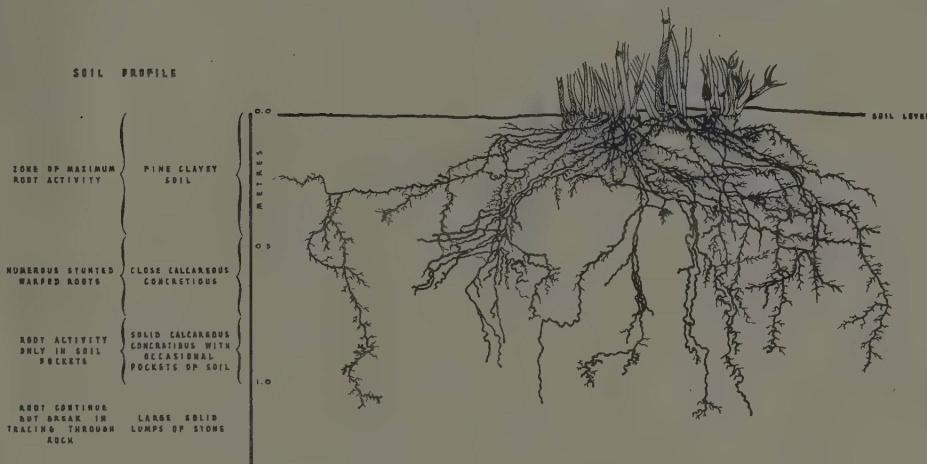
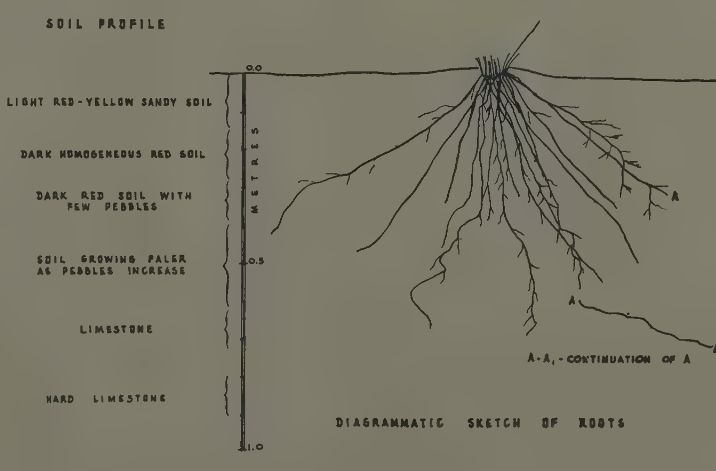


DIAGRAM 8

ARISTIDA KELLERI HACK. VERN. "BIRHE"

ALABLAH BALLEH, 8TH OCTOBER 1945



DIAGRAMMATIC SKETCH OF ROOTS

DIAGRAM 9

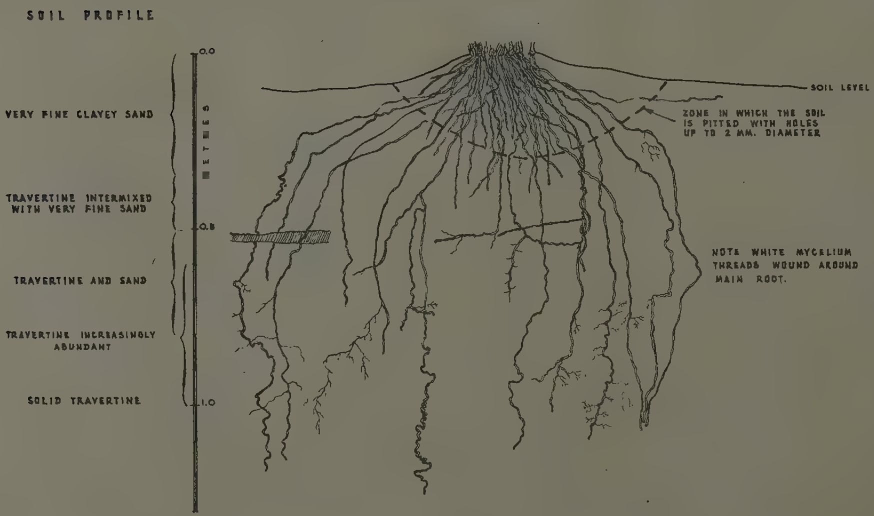
ARISTIDA PAPPOSA TRIN. AND RUPR. VERN. "MACHEN"

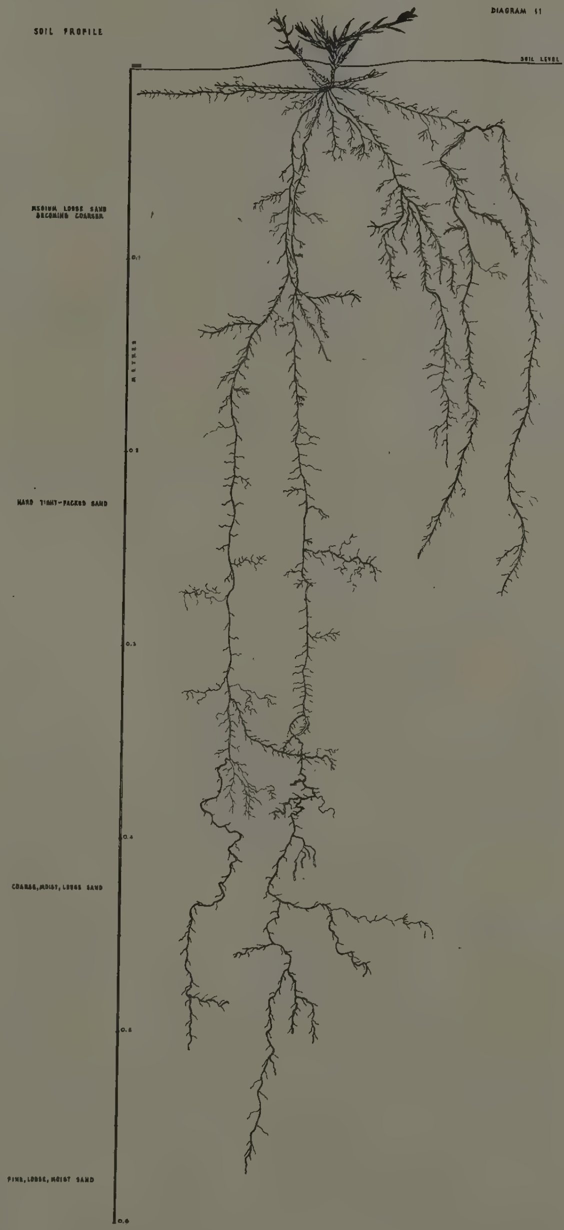
ALABLAH, 8TH OCTOBER 1945

DIAGRAM 10

CHRYSOPOGON AUCHERI (BOISS.) STAPF. "DAREMO"

JERIN, 18TH AUGUST 1945





ERAGROSTIS HARARENSIS CHIOV. VERN. "GUBANGUB"
SILIL TUG, 5TH MARCH 1945

DIAGRAM 13

ROOT BISECT OF PANICUM TURGIDUM FORSK. "DUNGARA" (SOMALI)
BISECT ON TUG WALL 2 MILES EAST OF SILIL PUMPING STATION 5th MARCH 1945

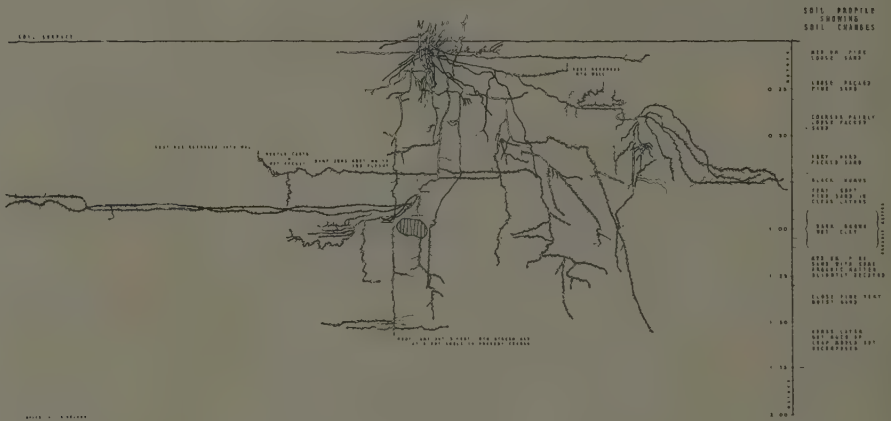
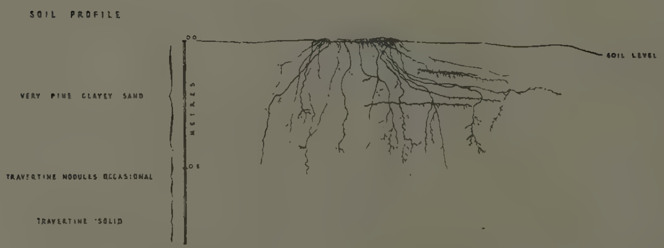


DIAGRAM 14

SPOROBOLUS MARGINATUS HOCHST. VERN. "DIHI"
JERIN, 18th AUGUST 1945



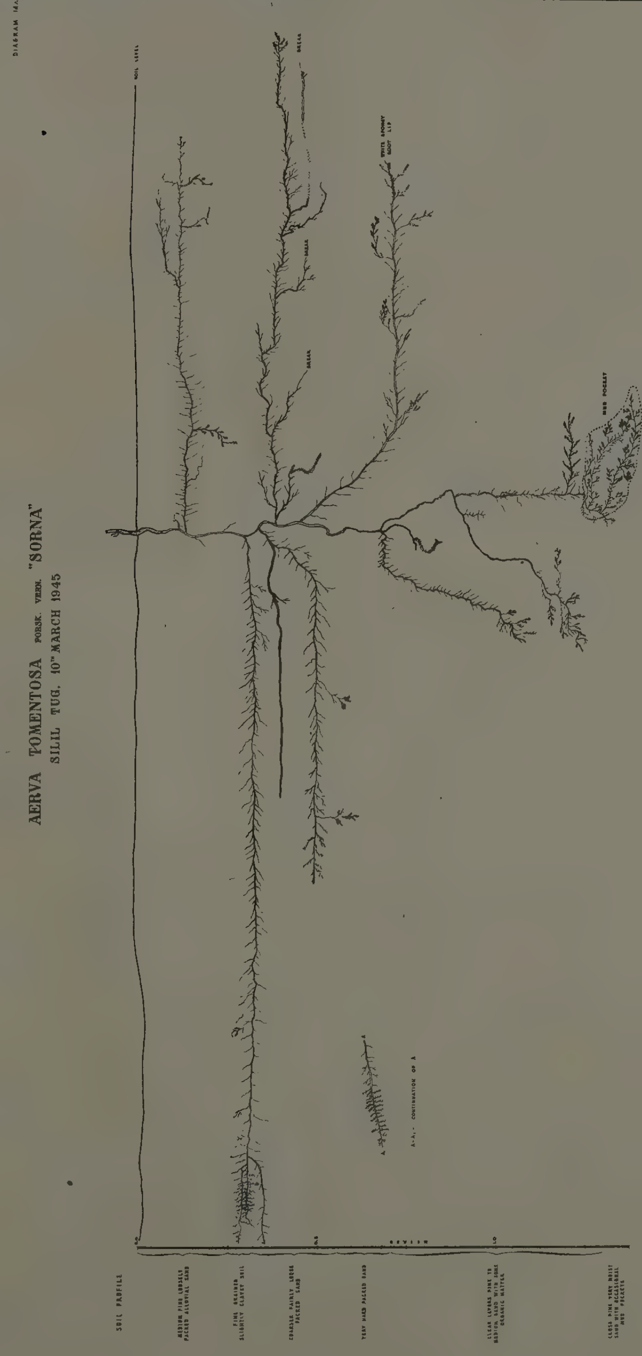


DIAGRAM 14A.
AERVA TOMENTOSA FORSK. VERN. "SORNA"
SILIL TUG. 10th MARCH 1945
SOIL LEVEL
BREAK
WHITE SPONGY ROOT TIP
MUD POCKET
A–A1 – CONTINUATION OF A
0
0.5
1.0
SOIL PROFILE
MEDIUM FINE LOOSELY PACKED ALLUVIAL SAND
FINE GRAINED SLIGHTLY CLAYEY SOIL
COARSE FAIRLY LOOSE PACKED SAND
VERY HARD PACKED SAND
CLEAR LAYERS FINE TO MEDIUM SAND WITH SOME ORGANIC MATTER
CLOSE FINE VERY MOIST SAND WITH OCCASIONAL MUD POCKETS

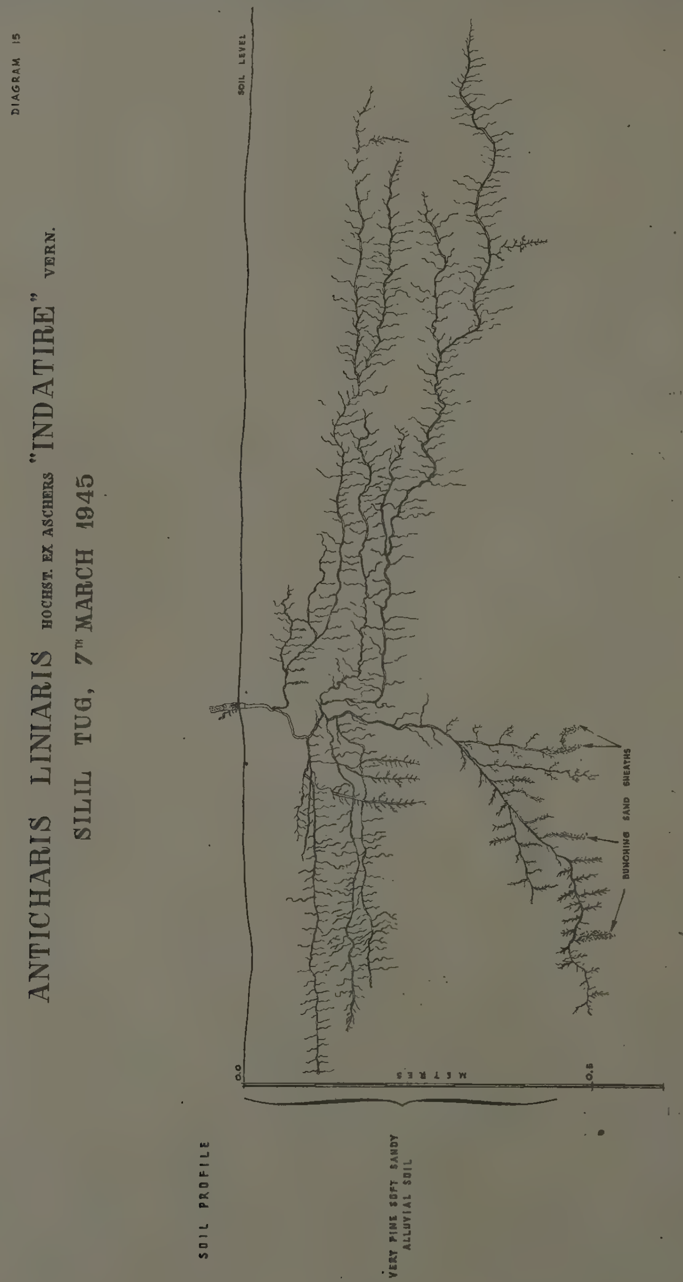


DIAGRAM 15
ANTICHARIS LINIARIS HOCHST. EX ASCHERS "INDATIRE" VERN.
SILIL TUG, 7TH MARCH 1945
SOIL LEVEL
BUNCHING SAND SHEATHS
0.0
METRES
0.5
SOIL PROFILE
VERY FINE SOFT SANDY
ALLUVIAL SOIL

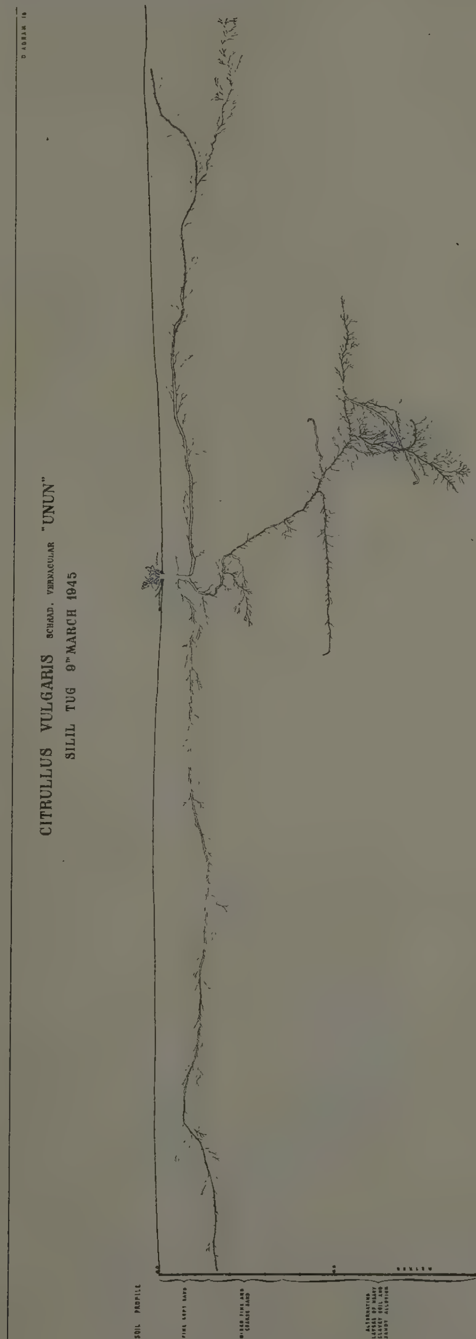

CITRULLUS VULGARIS SCHRAD. VERNACULAR "UNUN"
SILIL TUG 9th MARCH 1945
SOIL PROFILE
FINE SOFT SAND
MIXED FINE AND COARSE SAND
ALTERNATING LAYERS OF HEAVY CLAYEY SOIL AND SANDY ALLUVIUM

DIAGRAM 17

INDIGOFERA RUSPOLI BAK. F. "JELAB" (VERN.)

GED DOBO, LOWER SHEIKH, MAY 1945

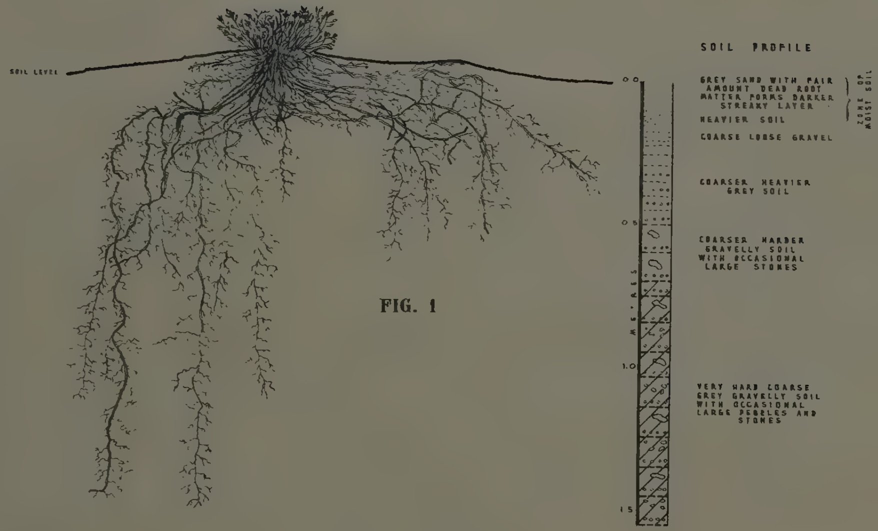


FIG. 1

FIG. 2

FIG. 3

FIG. 1 ROOT BISECT AND SOIL PROFILE
FIG. 2 PIECE OF STEM AND LEAF ENLARGED
FIG. 3 ROOTLET SHOWING NODULES

DIAGRAM 18

INDIGOFERA SPINOSA FORSK "MACHIN" (VERN.)

GED DOBO, LOWER SHEIKH, 18TH MAY 1945

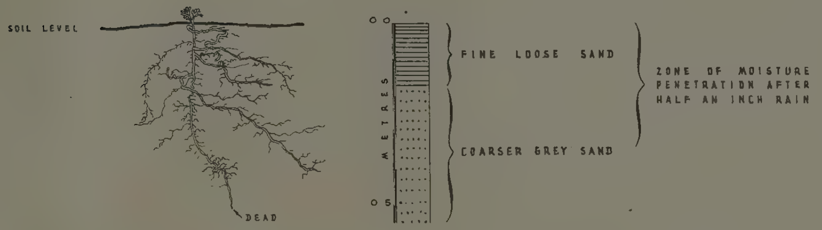


FIG. 1

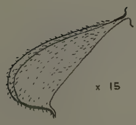


FIG. 2

FIG. 3

FIG. 4

FIG. 1 ROOT BISECT AND SOIL PROFILE

FIG. 2 LEAF ENLARGED

FIG. 3 GROWING TIP OF SHOOT SHOWING SPINES

FIG. 4 ROOTLET SHOWING MINUTE ROOTLETS AND NODULES

DIAGRAM 19

OLDENLANDIA SP. VERNACULAR "MANJAASO"

SILIL TUG, 8TH MARCH 1945

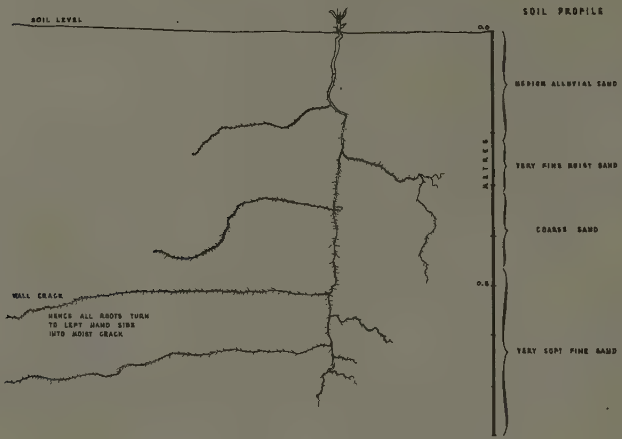


DIAGRAM 20

MOLLUGO SP.

SILIL, 7TH MARCH 1945

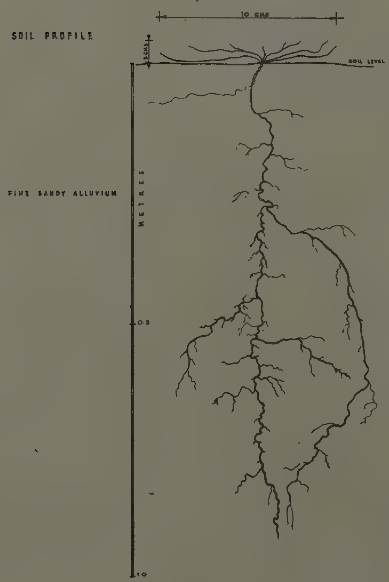


DIAGRAM 21

SIDA SP. VERNACULAR "MIRAGEL JIRA"

SILIL TUG, 8TH MARCH 1945

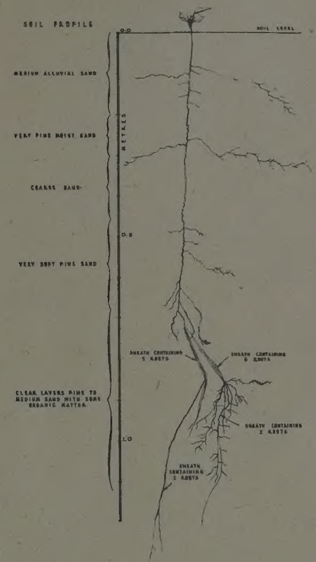


DIAGRAM 22

TEPHROSIA SP.

SILIL TUG, 8TH MARCH 1945

VERN. "FARADER, TIMADER OR LEBI-YERO"